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THESIS

Throughput Analysis Between High End
Workstations Across an
FDDI Network

by

Mark A. Schivley

June 1994

Thesis Advisor:

G.M. Lundy

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***Throughput Analysis Between High End
Workstations Across an
FDDI Network***

by
Mark A. Schivley
Captain, United States Army

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF COMPUTER SCIENCE

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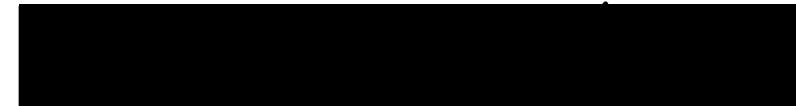
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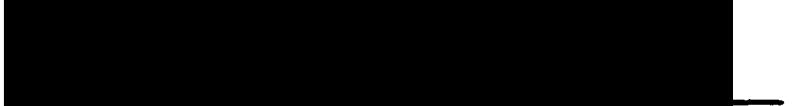


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ABSTRACT

Recently developed high speed networks are capable of transmitting data at rates of 100 Mbps or more. One such network protocol is Fiber Distributed Data Interface (FDDI). This network has a physical transmission rate of 100 Mbps. Analytical and simulation studies have shown that the FDDI protocol should provide actual throughput of 80% to 95% of this physical rate. Can the end user expect to see this kind of performance? If not, then what kind of throughput can actually be expected and where are the bottle necks?

In order to answer these and other related questions, two areas were studied: First, a performance comparison between a 40MHz SPARCstation 10 workstation and a 50MHz SPARCstation 10 workstation was conducted using the Neal Nelson commercial benchmark tool. Next, a well-known network measurement tool, *ttcp*, was used to obtain data transfer rates while varying several tunable operating system and network parameters. The parameters varied were: Target Token Rotation Time, TCP/IP window size, NFS asynchronous threads, Logical Link buffer size and Maximum Transfer Unit size. The results from the commercial benchmark analysis were used to determine if there are any differences which can affect transfer rates between the two workstations.

The results from the commercial benchmark tool clearly showed that the newer, higher speed processor is faster. The network tool *ttcp* showed that the TCP/IP window size had the largest impact on throughput performance. Throughput more than doubles from a window size of 4k to a window size of 20k. This is followed by having more than one workstation transmitting data simultaneously. Having two workstations transmitting nearly halves throughput. This is followed by having a faster processor. A measurement of file transfers using *rcp* system calls showed that the largest impact on file transfer speed is the overhead of receiving the transferred file.

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I. INTRODUCTION

A. BACKGROUND

Data communication networks are now an essential part of our society. Our technology base has given us workstations which can process data at speeds which makes mainframes from just a few years ago look slow in comparison. Now, not only must we process the data faster, but we also distribute the information to other locations at speeds which just a few years ago were impossible. We truly are in the information era.

In the 1960s and 1970s, the computer industry worked hard to develop new technologies which would give us faster, more powerful computers. The dramatic advances in integrated circuits technology made possible the wide availability of larger, more powerful super computers, low-cost workstations, and personal computers [ALBE94]. There were the companies which believed that the large, centralized processors were the solution to everyone's problems. At the same time, other companies developed smaller computers called minicomputers. These minicomputers, and their successors, desktop workstations, started filling the needs of small companies and universities which couldn't afford the cost of large mainframes and did not need the processing power provided by the large, all in one solution provided by the mainframe.

In the world of mainframes, the need to distribute data to other computers was not critical. The single mainframe would handle all of a company's processing needs. If there was a need to handle additional processing, the manufacturer of that mainframe provided a solution which would allow their mainframe to communicate with another of their mainframes. This of course ensured that the company or university continued to buy all or most of their computer equipment from the same computer manufacture.

With the growth of the minicomputers and the workstations came the need to connect these less expensive and less powerful machines. This provided the motivation and the

driving force behind the development of Local Area Networks (LAN). There were the proprietary options provided by the computer manufactures. However, with the need to provide connectivity between systems came the desire to have connectivity between systems from different manufacturers. This was very difficult without some sort of agreed upon standards. In the late 1970s, the International Standards Organization (ISO) developed the Open Systems Interconnection (OSI) reference model to serve as the basis for future open networks. This model would provide the basis for computers from different vendors to be able to communicate with each other [ALBE94].

Now we have the beginnings of connectivity between computers and the beginnings of smaller, more powerful computers. In the 1980s, Sun Microsystems started producing their line of desktop workstations. Within a few years, these workstations were being based on new Reduced Instruction Set Computer (RISC) technology which allowed Sun Microsystems and other companies to produce faster, more powerful workstations. Now if we combine the advancements of the desktop workstations with the advancements made in networks, we have the true beginnings of the information era.

The question now becomes one of which technology is advancing faster. Are we producing workstations which can exceed the capability of the networks or are the networks staying ahead of the abilities of the workstations. Also, advancements in workstation technology isn't just limited to faster hardware. Is the operating system and its networking tools keeping pace with current demands?

It is clear that the workstations are faster and more powerful than in the past. It is also clear that the networks can handle more data at faster rates than in the past. But where do we stand if we compare a recently released product produced by Sun Microsystems with one of the current high speed networks such as Fiber Distributed Data Interface (FDDI)?

B. OBJECTIVE

The objective of this thesis will be to measure actual throughput between high performance workstations over an FDDI network to determine what bottlenecks, if any,

exists between Sun Microsystem SPARCstationTM 10 multiprocessors running SolarisTM 2.3 and the Network PeripheralTM SBus FDDI Network Interface cards and to evaluate Transmission Control Protocol/Internet Protocol (TCP/IP) as a high speed transport protocol. This process will require an analysis of the workstations being used in this study, an understanding of current network operating system tools and measurements of data transfers across the network being tested.

This is not simply a matter of reading the vendor's promotional literature and seeing which aspect of the distributed processing environment is more capable. Vendors normally promote those aspects of their products which they can demonstrate as performing at or above some threshold. This threshold may or may not be value to the consumer.

C. SCOPE, LIMITATIONS AND ASSUMPTIONS

The scope of this investigation is limited to performing testing and tuning at the level available to any system administrator. No modifications are made to any hardware or changes made to the workstation kernel which are not considered tunable parameters. From this investigation, a determination will be made as to whether or not there are any bottlenecks.

It is assumed that the changes made and the results observed on the SPARC 10 multiprocessors running Solaris 2.3 can be extrapolated to other vendor's hardware and software. If we note that changing the TCP/IP window size on our workstations results in a 10 fold increase in throughput, then we assume comparable results would be observed on other vendor's workstations.

D. ORGANIZATION OF THESIS

This thesis is organized into seven chapters. This chapter provides the introduction and scope of work to be performed. Chapters II and III provide a background on networks in general, FDDI specifically and the specifics on the workstations involved in this investigation. Chapters IV and V cover the methodology, test results and analysis of results. Chapter VI covers what conclusions can be derived from these results.

II. NETWORK PROTOCOLS

A. NETWORKING THEORY

The primary focus behind the development of network protocols has been the organization of the protocol into a series of layers. This has allowed the design of the protocols to be simplified by focusing attention at each layer upon that layer's function and its interaction with the layers above and below. The purpose of each layer is to offer certain services to the layer above without the higher layer needing to know how those services were provided.

When designing a network protocol the network designer must determine how many layers the protocol will have, what those layers will do and how the layers will communicate with each other. This last decision, deciding how the layers will communicate, is one of the more important considerations. A clean-cut interface must be defined which will minimize the amount of information that must be passed between layers.

The set of layers and protocols is known as the network architecture. Enough specification must be given for each layer of the protocols so that vendors can write their versions of the protocol for their computer architecture. This is what makes the network architectures beneficial to everyone accessing a network. By having an agreed upon network architecture that everyone is willing to use, we can have distributed processing over heterogeneous processors [MINO91].

B. OPEN SYSTEM INTERCONNECTION

The Open System Interconnection (OSI) reference model, Figure 1, was proposed in 1978 to promote compatibility between network designs. This model was approved as a standard [ALBE94] in 1983 by the International Standards Organization (ISO). The reference model is not a protocol or set of rules but a layering of required functions, or

services, that provides a framework with which to define protocols. In practical terms, OSI is seen as a means of developing communications networks which are not restricted by the need to conform to a rigid set of manufacturers' proprietary standards and protocols.

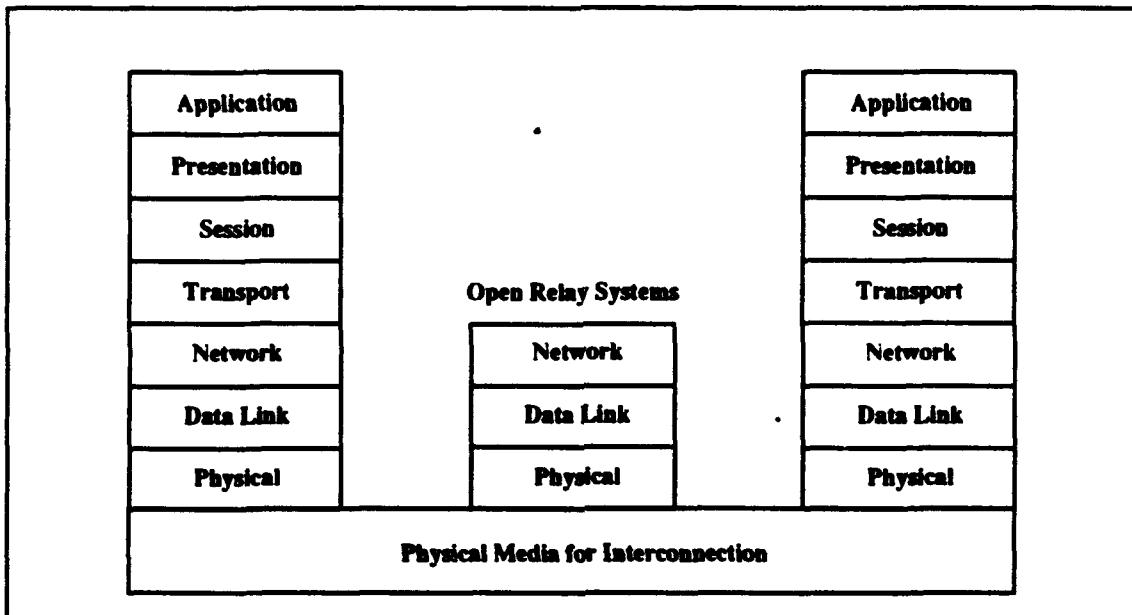


Figure 1: ISO-OSI Reference Model

The purpose of these seven layers is to define the various functions that must be carried out when two machines communicate. Each of the seven layers is architecturally independent, so that the relevant protocols and service functions of each layer can be developed independently. The seven layers of the model can be roughly divided into two parts; the first four layers, physical to transport, provide the telecommunications functions and operate on a node-to-node basis. The top three layers, session to application, are concerned mainly with carrying out processing functions and creating a meaningful dialog between the user and the application.

Below are the seven layers of the OSI model [STAL91]:

- Layer 1: Physical Layer
- Layer 2: Data Link Layer
- Layer 3: Network Layer

- Layer 4: Transport Layer
- Layer 5: Session Layer
- Layer 6: Presentation Layer
- Layer 7: Application Layer

C. TRANSMISSION CONTROL PROTOCOL/INTERNET PROTOCOL

The Transmission Control Protocol/Internet Protocol (TCP/IP) protocol is also structured as a series of layers. Each layer is designed for a specific purpose. They are designed so that a specific layer on one machine sends or receives exactly the same object sent or received by its twin on another machine. This is done without regard to what is going on in layers above or below the layer under consideration.

The advantage of layering is that it simplifies protocol design. The designer can concentrate on a specific layer without regard to the design of other layers. For example, when designing the transport layer of the protocol, the engineer need be concerned only with assuring that a packet received by one machine is identical to the packet sent by another. The message contained in the packet is of no concern. The integrity of the message is of concern only to the designer of the application layer.

Members of the TCP/IP family include the Internet Protocol (IP), Transmission Control Protocol (TCP), User Datagram Protocol (UDP), Address Resolution Protocol (ARP), Reverse Address Resolution Protocol (RARP), and the Internet Control Message Protocol (ICMP). The entire family may be referred to as TCP/IP, reflecting the names of the two main protocols.

The OSI model describes an idealized network communications model. TCP/IP does not correspond to this model at every level, but instead either combines the functions of several OSI layers into a single layer, or finds no need to make use of certain layers. In consequence, TCP/IP can be described by a simpler model as shown in Figure 2 [STEV94].

1. Link Layer

The Link layer is the hardware level of the protocol model. It specifies the physical connections between hosts and networks, and the procedures used to transfer packets between machines.

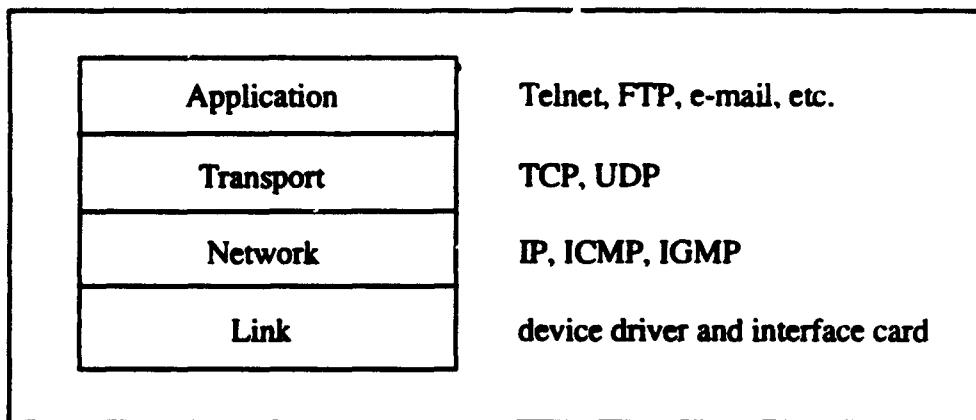


Figure 2: The Four Layers of the TCP/IP Protocol Suite

2. Network Layer

This layer is responsible for machine-to-machine communications. It determines the path a transmission must take, based on the receiving machine's IP address. The network layer also provides transmission formatting services; it assembles data for transmission into an internet datagram. If the datagram is outgoing (received from the higher layer protocols), the network layer attaches an IP header (Figure 3) to it. This header contains a number of parameters, most significantly the IP addresses of the sending and receiving host. Other parameters include datagram length and identifying information, in case the datagram exceeds the allowable byte size for network packets and must be fragmented.

3. Transport Layer

The transport layer protocols enable communications between application programs running on separate machines. The transport layer assures that data arrives in

sequence, and without error. It does so by swapping acknowledgments of data reception, and the retransmission of lost packets. This type of communication is known as "end-to-end". Protocols at this level are TCP, UDP, and ICMP.

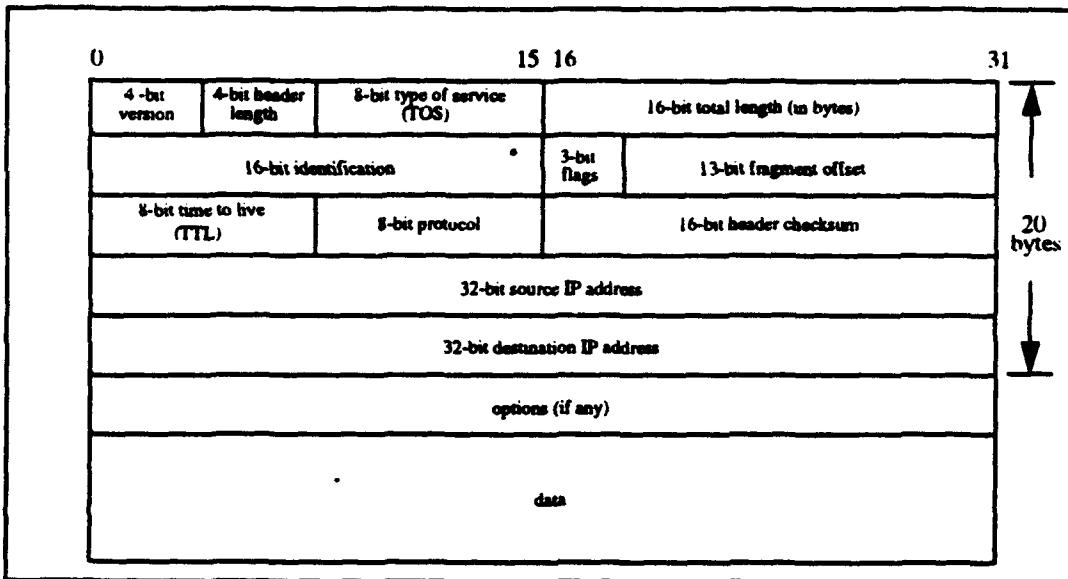


Figure 3: IP Header

TCP attaches a header onto the transmitted data. This header contains a large number of parameters, see Figure 4, which help processes on the sending machine connect to peer processes on the receiving machine. TCP uses 16 bit port numbers as its addressing method. Servers are normally known by their well-known port number. For example, every TCP/IP implementation that provides an FTP server provides that service on TCP port 21. Every Telnet server is on TCP port 23 [STEV94].

4. Application Layer

The application layer lets you use various TCP/IP standard internet services. These services work with the next lowest level of protocols (transport) to send and receive data. These services include *telnet*, *ftp*, *rcp*, and the Domain Name Service (DNS).

***telnet*.** The Telnet protocol enables terminals and terminal oriented processes to communicate on a network running TCP/IP.

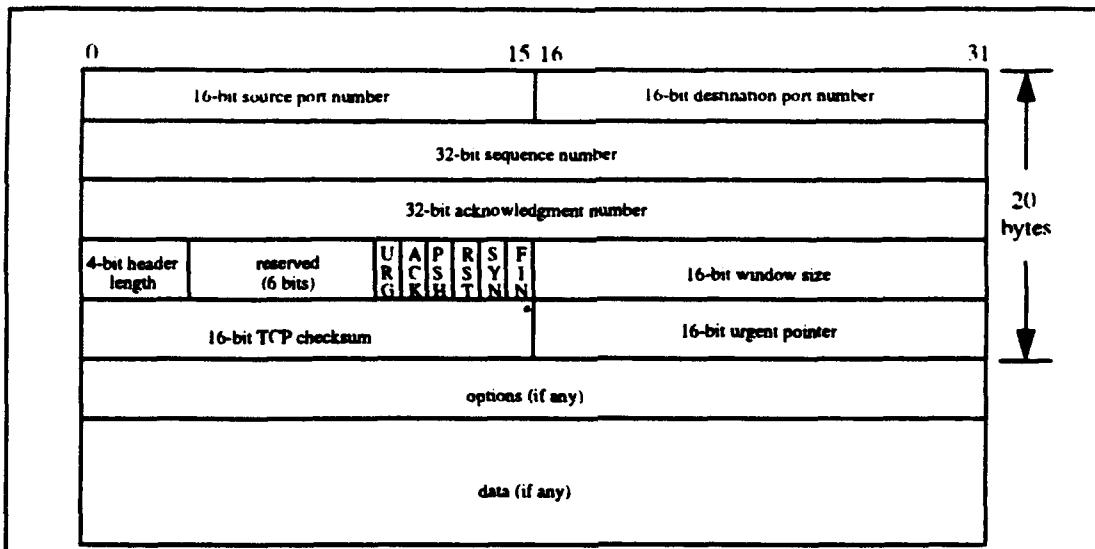


Figure 4: TCP Header

ftp. *ftp* transfers files to and from a remote network. Unlike *rcp*, *ftp* works even when the remote computer is running a non-UNIX operating system. A user must “log in” to the remote computer to make an *ftp* connection unless a system administrator has set up the computer to allow “anonymous ftp”.

rcp. *rcp* copies one or more files or hierarchies to and from a remote computer. The remote computer must be running UNIX. One must be an accepted user of the remote computer (i.e., the user’s name must be in the remote computer’s password database, and the user’s machine name must be listed in the remote *rhost* file). If this is not the case, a user cannot copy anything to or from the remote machine. The user must know the complete pathname of the file or directory to be copied.

DNS. DNS provides host names to the IP address service. It is a distributed database that is used by TCP/IP applications to map between hostnames and IP addresses. The DNS provides the protocol that allows clients and servers to communicate with each other and to provide electronic mail routing information.

D. FIBER DISTRIBUTED DATA INTERFACE

1. Fiber Distributed Data Interface Basics

Fiber Distributed Data Interface (FDDI) is a 100 Mbps high speed LAN standard developed under the auspices of American National Standards Institute (ANSI) X3T9.5 committee. FDDI was developed to create a reliable fault-tolerant, high-speed network connecting numerous stations over greater distances than existing standards. Although FDDI is somewhat similar to the IEEE 802 standards, it is not part of that family of standards [MINO91].

The ANSI X3T9.5 committee developed specifications for a network based on a dual counter-rotating fiber optic ring using a timed-token protocol, which is capable of transmitting data at 100 Mbps in each ring and which can extend to 500 stations over total fiber length of 200 km with full system performance. The dual counter-rotating ring can support connections up to 2 km with multimode fiber and connections up to 60 km using single-mode fiber.

The FDDI standard allows for two types of traffic: synchronous and asynchronous. Synchronous traffic should consist of data which is time sensitive such as voice or interactive video. Any delay in the throughput of this traffic has an adverse affect of the quality of the data being transferred. Asynchronous traffic should consist of more routine data transfers such as email, file transfers and Network File System (NFS) or Network Information Service (NIS) traffic. These packets of data can sustain some reasonable delays in transmission without any adverse affects on the applications.

2. Fiber Distributed Data Interface Layers

The standard for FDDI developed by the X3T9.5 committee included four layers shown in Figure 5. They are the Media Access control (MAC) layer, the Physical (PHY) layer, the Physical Medium Dependent (PMD) layer, and the Station Management (SMT) document [ALBE94].

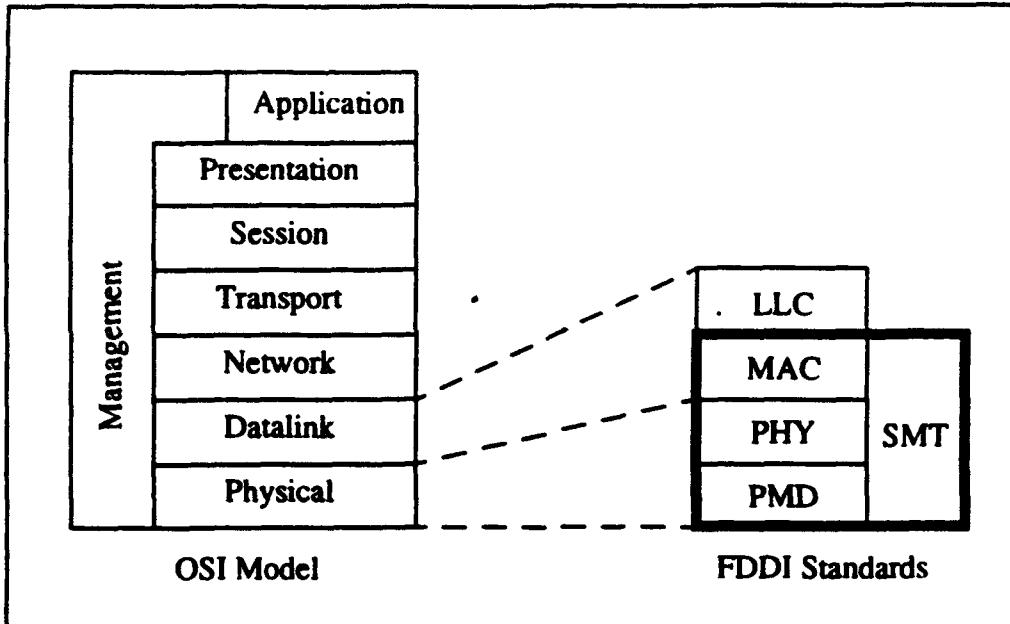


Figure 5: Relationship Between FDDI and ISO-OSI Layers

The four layers of FDDI fall under the first two layers of the OSI Model. The physical layer of FDDI is specified in two documents: the FDDI PMD which defines the optical interconnecting components used to form links and the FDDI PHY which defines the encoding scheme used to represent data and control symbols. The DLL is also divided into two sublayers: A MAC and LLC layer. The MAC portion provides access to the medium, address recognition, and generation and verification of frame check sequences. The LLC specification is not part of the FDDI standard [MINO91].

Below in Figure 6 is an additional graphical representation of the interaction between the FDDI standards as described in [POWE93].

a. *The Physical Medium Dependent Layer*

This layer defines all transmitters, receivers, cables, connectors and other physical media and hardware. There are currently 6 media options provided for the PMD layer:

- Multimode fiber (PMD)
- Single-mode fiber (SMF-PMD)
- Low-cost fiber (LCF-PMD)
- Shielded twisted pair (STP-PMD)
- Unshielded twisted pair (UTP-PMD)
- FDDI on Synchronous Optical Network (SONET)

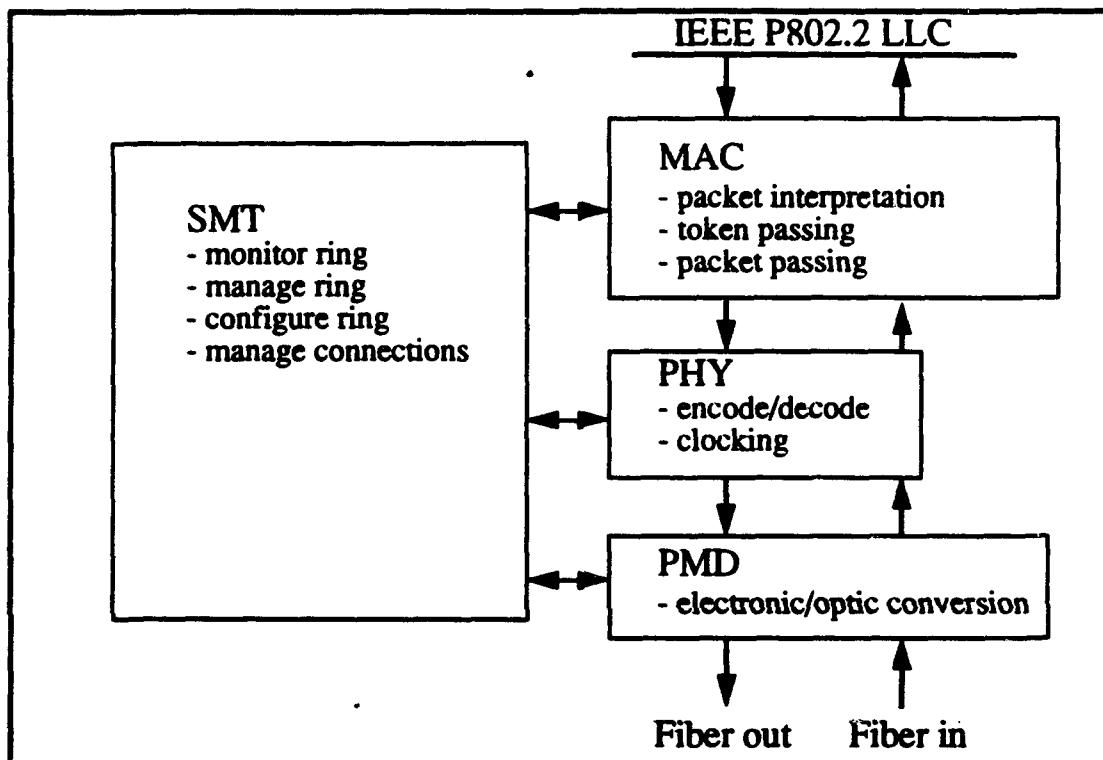


Figure 6: Block Diagram of the FDDI Layers

The first three options are published or soon to be published standards. The last three options are under development [ALBE94].

The PMD layer provides the PHY layer all the services required to transport a coded bit stream from one node to the next node. It converts the encoded data requests from the PHY layer into either optical or electrical signals depending on the media being used. It also provides SMT with the needed services required for proper ring management. The PMD layer informs both the SMT and PHY layers whenever it detects a signal on the medium [ALBE94].

b. The Physical Layer

This layer provides media independent functions associated with the OSI physical layer. The PHY layer decodes incoming bit stream into a symbol stream for use by the MAC layer and it encodes the data and control symbols provided by the MAC layer for transmission via the PMD layer. The PHY layer continuously monitors the ring status by listening to incoming signals and passes this information onto the SMT layer [ALBE94].

c. The Media Access Control Layer

This layer provides fair and deterministic access to the network. The access is fair because a workstation's physical location does not give it any advantage in accessing the medium over another workstation's location. The service is deterministic implies that the time the workstation has to wait for the token can be predicted under error free conditions.

In FDDI, medium access is controlled by a token. The workstation which possesses the token can transmit frames. The other workstations on the network repeat the frame, and the destination workstation copies the frame in addition to repeating it. The MAC layer of the workstation which generated the frame is responsible for removing the frame and passing the token downstream to the next workstation when it's Token Holding Time (THT) has expired [ALBE94].

d. The Station Management Layer

The SMT layer provides services such as node initialization, bypassing faulty nodes, coordination of node insertion and removal, fault isolation and recovery and collection of statistics. The SMT layer provides these functions using services provided by the PMD, PHY and MAC layers.

3. Fiber Distributed Data Interface Framing

Most communications within FDDI is done on frames (Except Physical Connection Management (PCM) signaling). Within the MAC layer there are three frame types:

- Tokens
- Management frames
- Data frames

Each frame is made up of three parts. The first part is the start of the frame sequence. The next part is the data or information part of the frame. The last part is the end of the frame sequence. The data frame is shown in Figure 7 along with the size of each field in symbols [ALBE94].

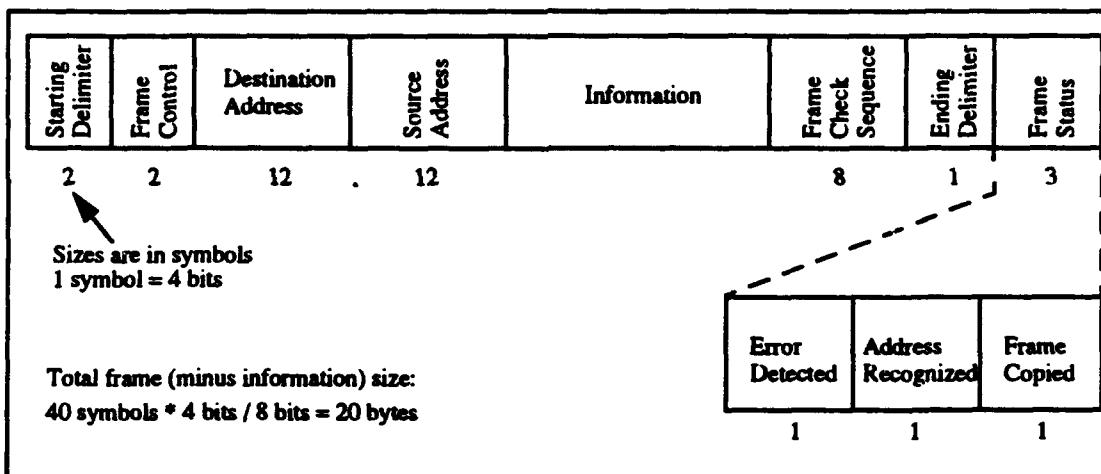


Figure 7: FDDI Frame Format

The start part of the frame is 28 symbols in length. Each symbol is a 4 bit unit. This means the start portion of the FDDI frame is $28 \text{ symbols} * 4 \text{ bits} / 8 \text{ bits} = 14 \text{ bytes}$ long. The end portion of the FDDI frame is 12 symbols or 6 bytes long. Since the maximum frame length is 9,000 symbols or 4,500 bytes, this leaves 4,480 bytes available for data or information. This remaining portion of 4,480 bytes, is also known as the FDDI Maximum Transfer Unit (MTU) value [ALBE94].

4. Encoding Method

Digital data needs to be encoded for proper transmission. The type of encoding used is determined by the type of media being used, the desired data rate, noise present on the transmission media and other factors. Since FDDI was originally intended for use over fiber optics, the encoding method selected needed to provide a digital-to-analog capability.

FDDI uses a two-stage encoding scheme: 4B/5B group encoding along with the digital signal encoding method known as Non-Return to Zero Inverted (NRZI). NRZI is an example of differential encoding. The signal is decoded by comparing the polarity of adjacent signal elements rather than determining the absolute value of a signal element. In 4B/5B, the encoding is done 4 bits at a time resulting 5 encoded bits. Then, each element of the 4B/5B stream is treated as a binary value and encoded using NRZI.

The result is that FDDI is able to achieve a 100 Mbps throughput using a 125-MHz rate. As mentioned earlier, the PHY layer is responsible for decoding the 4B/5B NRZI signal from the network into symbols that can be recognized by the station. The synchronization is derived from the incoming signal and the data are then retimed to an internal clock through an elasticity buffer.

E. NETWORK OVERHEAD

The process of transferring data from one workstation to another involves all the layers of protocols described previously. Even though the protocols are broken into layers to distribute functionality, the result is increased overhead. As discussed earlier, for each layer of protocol, there is an associated overhead at that layer as shown in Figure 8.

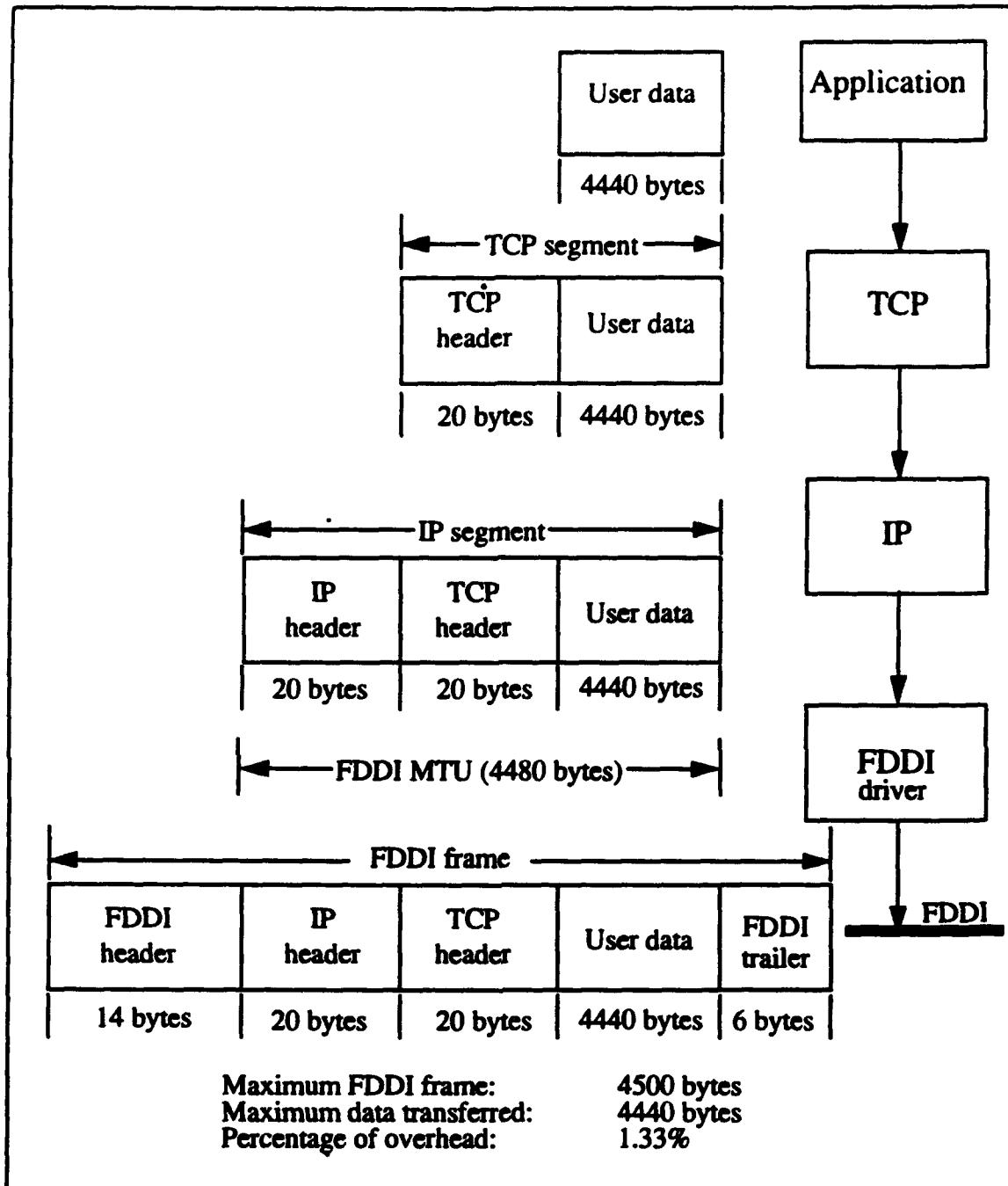


Figure 8: Composition of FDDI Frames and Percentage of Overhead

The amount of overhead involved in transferring data is dependent upon the protocols used and the network media being used as the transfer agent. For FDDI, the overhead is calculated as follows:

Data	Overhead	Level	Total Overhead
4,440 bytes	0	Application	0 bytes
4,440 bytes	20 bytes	TCP	20 bytes
4,440 bytes	20 bytes	IP	40 bytes
4,440 bytes	20 bytes	FDDI	60 bytes

In this example, the frame of data being sent is 4,500 bytes: total amount of data being transferred is 4,440 bytes and total amount of overhead is 60 bytes. Therefore, the percentage of overhead is the amount of overhead (60 bytes) divided by the total frame size (4,500 bytes). Overhead = 60 bytes / 4,500 bytes = 1.33%. If we were to only send 11 bytes of data, then the overhead would be 60 bytes / 71 bytes = 84.5%. It is clear that the more data sent in each FDDI frame, the lower the percentage of overhead associated with that frame. Note that in this example the overhead from the application layer was not included.

F. FIBER DATA DISTRIBUTED INTERFACE PARAMETERS

This section will give a brief explanation of FDDI parameters as covered in the ANSI standards. The MAC layer must implement a number of these parameters as timers and counters. The three main goals of these timers and counters are to [ALBE94]:

- Allow the initialization of the token rotation timer
- Permit fast recovery from ring errors
- Aid in the collection of ring statistics for SMT

Below in Figure 9 are a list of the important timer values and variables used in the data transmission process. According to the FDDI standards, every time a node releases a token, it loads the value of T_{Opr} into Token Rotation Timer (TRT). This timer then decrements until it reaches zero. If it reaches zero before a valid token is received, the token is said to be late and the late counter ($Late_Ct$) is incremented. If TRT expires a second time before a valid token is received, an error condition exists and recovery procedures are initiated.

The token holding timer (THT) is used to control asynchronous transmission in a dynamic manner. When a valid token is received and the *Late_Ct* is not set, the token is said to be early and the node may transmit asynchronous data. In this case, THT is set to *T_Opr* minus TRT and the node may transmit until THT expires. TVX is a hardware backup timer that is used to prevent nodes from babbling on the network due to some error or miscalculation of THT [ALBE94].

Parameter	Description
TTRT	Target token rotation time
TRT	Token rotation timer
<i>T_Opr</i>	Operative TTTRT negotiated during claim process
<i>Late_Ct</i>	Late counter
THT	Token holding timer
TVX	Transmission valid timer

Figure 9: Timers and Counters Used in Data Transmission

III. NETWORK EQUIPMENT

A. NETWORK OVERVIEW

The Naval Postgraduate School (NPS) FDDI research network consist of the three machines operating on a ring. The names of the three machines on the FDDI LAN are "Black", "White" and "Gold". Gold is the server on the network. The network is setup as shown in Figure 10.

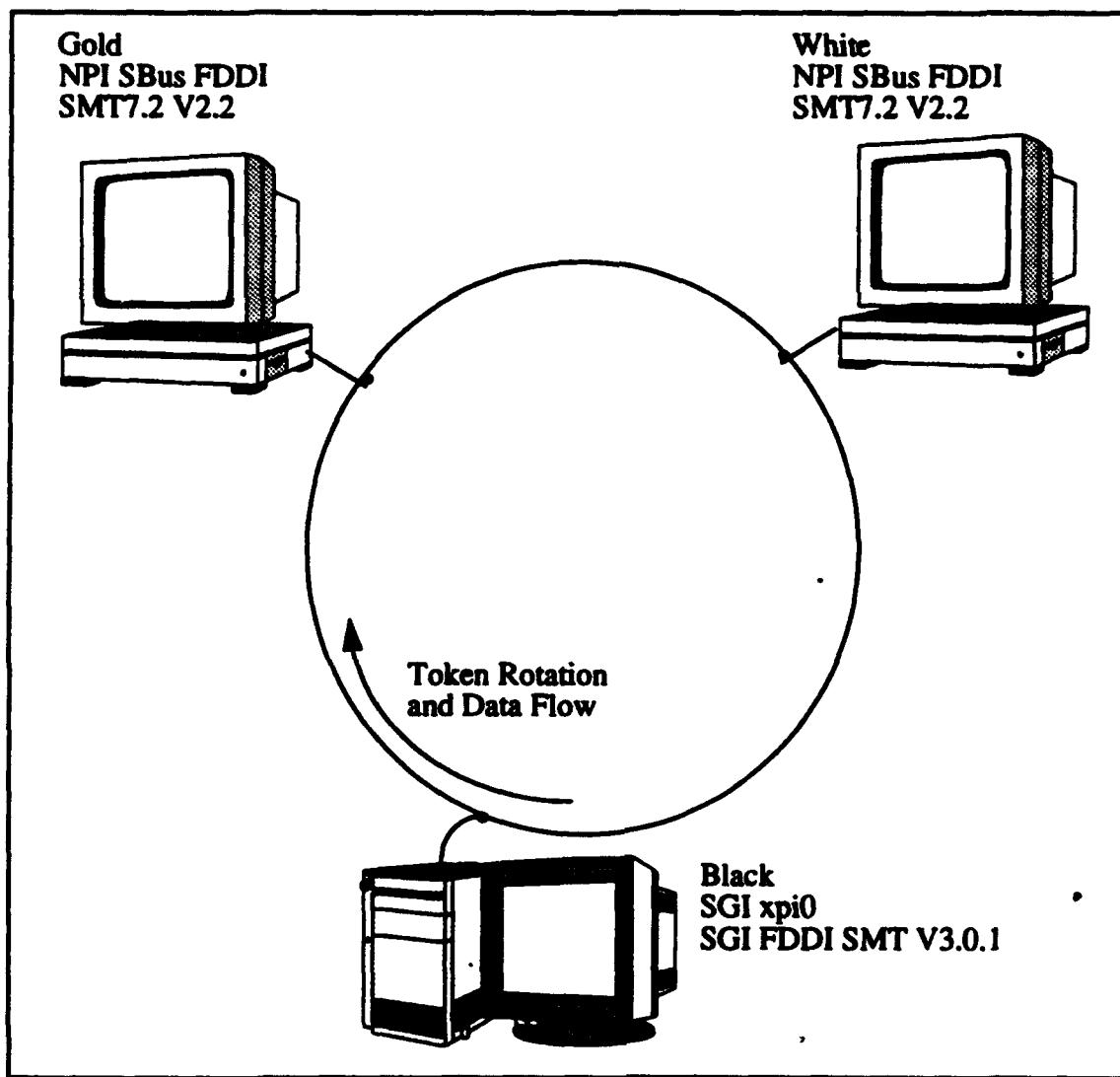


Figure 10: NPS's FDDI Research Network

1. Fiber Optics Equipment

The specifications for the fiber optics equipment can be found in the PMD standards. Originally, only optical fiber was specified as a physical media for FDDI. Now it is possible to also use shielded twisted-wire for short-distance transmissions. The requirements for twisted-wire can be found in the STP-PMD standards.

The recommended fiber size for FDDI is 62.5/125 μ m. The operating wavelength is specified as 1300 nm and the minimum allowable power for the transmitter is -16 dBm. Pin diodes are to be used in the link. Pin diodes were chosen over avalanche photodiodes since pin diodes are a more mature technology and would result in a lower cost receiver. The bit-error rate (BER) of the network is 4×10^{-11} and the maximum number of nodes is 500 [POWE93].

2. Network Peripherals' Interface.

The Network Peripherals Inc. (NPI) SBus FDDI Network Interface conforms to Sun Microsystems' requirements for an SBus adapter. It mounts in a SBus slot and implements burst mode Direct Memory Access (DMA) for the highest system performance [NPI93].

As stated earlier, FDDI is designed to provide the capability for both synchronous and asynchronous data transfer. This is not the case with NPI's SBus FDDI Interface card. Furthermore, it is not the case for all known current implementations of FDDI. This makes the relationship of the timers and counters described earlier not as well defined. Without synchronous and asynchronous transfers, there is no need for *Late_Ct* and THT. Below is a list of parameters which NPI list as its tunable parameters. Note that there is not a parameter listed here which specifies how long a node can maintain the token.

```
sbf_num_llc_rx      /* For LLC network traffic:  
/* number of 4k receive buffers, maximum is 64 4k buffers  
/* Default is 48 4k buffers per NP-SB adapter  
  
sbf_num_smt_rx      /* For SMT network traffic:
```

```
/* number of 4k receive buffers, maximum is 64 4k buffers  
/* Default is 4 4k buffers per NP-SB adapter  
  
sbf_mtu          /* Maximum protocol packet size, default is 4352 bytes  
  
sbf_T_Notify     /* SMT Neighbor Notification Timer, default is 30 seconds  
  
sbf_num_mcast    /* number of multicast entries, default is 16
```

These parameters can be tuned by entering the appropriate line below in /etc/system for each parameter.

1. To change number of receive buffers to 64:

```
set sbf:sbf_num_llc_rx = 64
```

2. To change MTU size to 4192 bytes:

```
set sbf:sbf_mtu = 4192
```

3. To change T_Notify timer to 10 seconds:

```
set sbf:sbf_T_Notify = 10
```

After contacting NPI it was learned that there is another parameter which is not advertised called *t_req*. This parameter determines how long the node is allowed to hold the token.

3. Silicon Graphic's Interface

FDDIXPressTM 3.0.1 is a network interface controller (board and software) providing FDDI connectivity for Silicon Graphics workstations and servers. For the IRIS Indigo, FDDIXPress has two configurations of the FDDI board: FDDIXPI and FDDIXPID. The FDDIXPI board allows one single-attachment FDDI connection to an FDDI concentrator; the FDDIXPID board provides a dual-attachment FDDI connection directly to the dual ring, or one or two connections to an FDDI concentrator. An Indigo can accommodate one of these boards.

When FDDIXPress is installed, an Indigo can also use its built-in Ethernet network interface, thus having two network interfaces. FDDIXPress for IRIS Indigo has been designed for customer installation.

B. WORKSTATION OVERVIEW

1. SUN SPARCstation 10 system

The SPARCstation 10 systems used in this test were the new multiprocessing systems running Solaris 2.3: We had two SPARCstation 10 systems, Gold and White, available for our FDDI research. Both systems have two processors, two internal hard disk drives and 224 Dynamic Random Access Memory (DRAM). Gold has two 50MHz processors and 2 - 1 GB internal drives. White has two 40MHz processors, 1 - 1 GB internal drive and 1-425 MB internal drive.

a. *Software Architecture*

Solaris 2.3 is a multilayered operating system that includes SunOS 5.3, Open Network Computing (ONC), Open Windows, and the DeskSet. At the core of Solaris is SunOS, the collection of programs that actually manages the system, which includes the kernel, the file system, and the shells.

SunOS is a collection of UNIX programs that control the Sun workstation and provide a link between the user, the workstation, and its resources. It has its roots firmly placed in the two most popular UNIX families: Berkeley UNIX (BSD) and AT&T's UNIX. Early versions of SunOS blended some of AT&T's UNIX with Berkeley UNIX and offered additional enhancements.

AT&T and Sun Microsystems later worked together to create a new industry standard, AT&T UNIX System V Release 4, commonly known as SVR4. SunOS 5.3 merges SunOS 4.1 and SVR4. Most of the new changes in SunOS come from SVR4. As a result, Solaris 2.3 is based on SVR4 but contains a few additional BSD/SunOS features [HESL93].

b. Hardware Architecture

The SPARCstation 10 architecture is shown in Figure 11 [SUNM90]:

SuperSPARC microprocessor This is a high-performance CPU chip that has the following features:

- A single chip with integer, floating point, memory management, and caches.
- Superscalar pipeline with up to three instructions launched per clock cycle.
- 20-Kbyte instruction cache and 16-Kbyte data cache.
- 64 entry TLB with hardware page-table walking.
- Integral support for cache-coherent multiprocessing.

The SuperSPARC processor has a companion chip, the SuperCache controller, which provides for a 1-Mbyte external cache. Additionally, SPARC modules with SuperCache controllers can operate asynchronous to the system clock.

MBus. The MBus is a high performance memory bus which was first introduced in Sun's SPARCserver 600MP family. It is a synchronous, 40-MHz 64-bit bus that is capable of a peak transfer rate of 320 Mbytes/second. Typically, the MBus can sustain a rate of 100 Mbytes/second.

This bus provides support for symmetric multiprocessing by means of a "snooping" protocol. Whenever a processor puts an address onto the MBus, all other processors "snoop" the bus, checking to see if data at the snooped address is in their cache.

Main memory architecture: The Sun-4m architecture uses a 144 bit wide memory data path (128 bits of data and 16 bits of error detection and correction). The use of a 128-bit wide memory data has two advantages. First, the 32-byte cache fill can be accomplished quickly. Second, error corrections can be performed on each 64-bit word. Single bit errors can be corrected and double-bit (4-bit) errors can be detected.

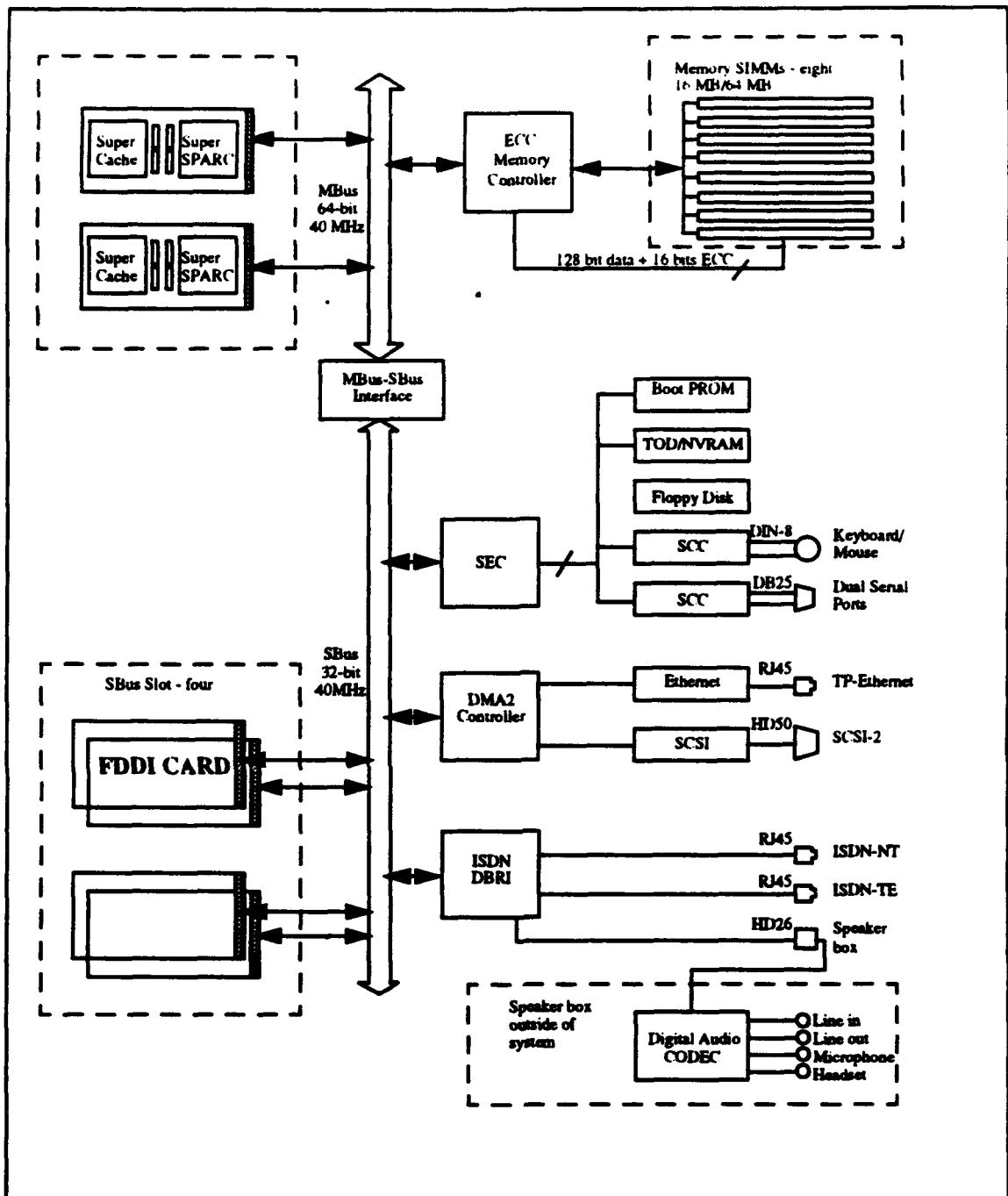


Figure 11: Sun-4m Architecture Used in the SPARCstation 10 System

I/O architecture: A single Application-Specific Integrated Circuit (ASIC) serves as the interface between the MBus and the SBus. The MBus is used as the processor memory interconnect, while the SBus is used only for I/O. The SPARCstation 10 system

supports four SBus slots. They provide the means to interface a variety of I/O options, including network interfaces such as FDDI, graphics adapters and laser printer interfaces.

2. Silicon Graphics IRIS Indigo

The Silicon Graphics IRIS Indigo used in this test was an IRIS-4DTM, model 4D/RPC. The IRIS Indigo uses the R3000A CPU RISC processor from MIPS Computer Systems Inc. It is assisted by a 32 Kbyte data and instruction cache and a MIPS R3010A floating-point unit. To speed up data transfers, IRIS Indigo uses custom ASICs designed by Silicon Graphics. These chips manage memory and processor interrupts, handle I/O and control the bus, often without CPU intervention [SILIC91].

We had one IRIS Indigo, Black, available for our FDDI research. This system has one 33 MHz processor, one 1 GB internal hard disk drive and 32 Mbytes of RAM. The workstation has the following features:

- A single 33 MHz chip with integer, floating point, memory management, and caches.
- 32-Kbyte instruction cache and 32-Kbyte data cache.
- Integral support for cache-coherent multiprocessing

a. Software Architecture.

The IRIS Indigo uses IRIX 4.0 which is Silicon Graphics' implementation of the UNIX operating system. IRIX 4.0 is based on AT&T UNIX System V.3, but also includes numerous 4.3 BSD extensions, such as TCP/IP network protocols and NFS, which provide transparent access to files across a heterogeneous network

b. Hardware Architecture.

This IRIS Indigo CPU board, Figure 12 [SILIC91], contains four functional sections:

- The processor core, which contains the CPU and FPU.
- Main memory, which contains DRAM and supporting circuitry
- The I/O system, which contains peripheral ports and hardware designed to read incoming data, manage incoming and outgoing data
- The audio system, which contains audio ports and digital signal processing hardware.

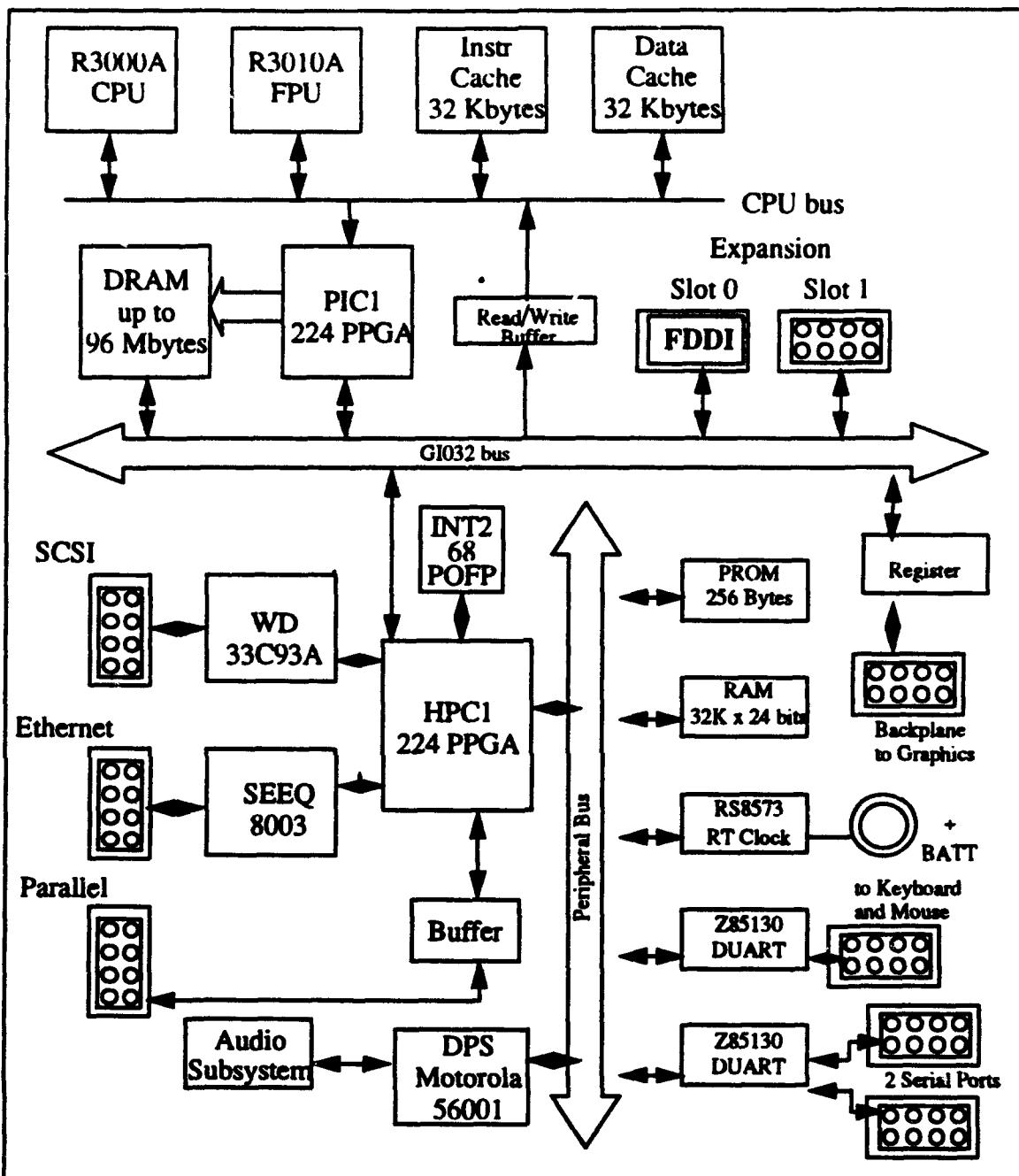


Figure 12: The IRIS Indigo CPU Board

Three busses connect parts of the CPU board:

- The CPU bus, which connects the CPU, FPU, cache control, and bus control hardware.
- The GIO32 bus, which is the main system bus connecting the processor core,

main memory, I/O system, expansion slots, and graphics board.

- The Peripheral bus, which connects the peripheral ports, audio system, and other I/O components.

The CPU bus and the GI032 bus have separate clocks and run at different speeds so that each part runs at maximum capability. The CPU and other chips can be upgraded independently as technology improves.

Instruction and Data Caches. Each cache is a 32 Kbyte cache. The instruction cache holds frequently used instructions and the data cache holds frequently used data. The IRIS Indigo uses a write-through scheme in the data cache to ensure that writes made to the cache are also written to the corresponding page in main memory.

The GI032 Bus. This bus is the IRIS Indigo's main system bus, and is designed for high speed data transfer. It connects the main systems of IRIS Indigo; the processor core, main memory, the I/O systems, the graphics system, and any systems plugged into the expansion slots. This bus is a synchronous, multiplexed address/data, burst mode bus that operates at 33.3 MHz, clocked independently of the CPU. The bus protocol supports data transfers at a maximum sustained rate of one word per clock.

The I/O System. The I/O system ties together a variety of I/O ports and the chips that drive them, a system clock, system Programmable Read-Only Memory (PROM) for booting up, an static RAM.

The HPC1 ASIC. The HPC1 is a custom Silicon Graphics chip that connects to the GI032 bus, the peripheral bus, and directly to several of the I/O ports. It is the heart of the I/O system, and quickly transfers data between main memory and a rich collection of peripheral devices.

Expansion Slots. The two expansion slots, connected directly to the GI032 bus, provide direct access to the system for Silicon Graphics and third party plug-in boards for such applications as high-speed networking, image compression, video deck control, and additional I/O. Slot 0 is used for our FDDI connection.

IV. TEST DESIGN PLAN

A. TEST STRATEGY

The objective is to find the upper limit of throughput by measuring actual throughput between high performance workstations over an FDDI network and to determine what bottlenecks, if any, exists between Sun Microsystem SPARC 10 multiprocessors running the Solaris 2.3 and NPI's FDDI network interface cards. This process will include identifying the various parameters which affect throughput and testing these parameters in enough detail to determine their impact on network performance. As explained in Chapter II, there are various levels of software that are involved in transferring data. As shown in Figure 13, as data is transferred from White to Gold, there are several impacts on the data transfer rate.

The key to this test design plan will be gathering the appropriate data to determine what impact these various parameters have on the transfer rate, and how to measure them. Three different methods will be used to measure the performance of data being transferred between workstations across the FDDI network. First, a commercial benchmarking tool will be used to provide performance results on the workstations. Second, a public domain networking benchmark tool will be used to show the transfer rate of the network. Third, a simple program which issues an *rcp* command and measures the time of the file transfer will be used.

B. NEAL NELSON BENCHMARK

The primary benchmarking tool to be used for providing the performance results on the workstations will be the Neal Nelson Business BenchmarkTM. This benchmark tool has been around for over 9 years and has been used as a tool for verifying vendor compliance during government contract awards. The Business Benchmark differs from other popular benchmarks in that its primary focus is not to provide a single number speed rating for a

system, nor is its primary purpose to emulate a particular user group or duplicate the load created by certain task mix. The Business Benchmark was designed to incrementally stress various parts of a computer system and record how the system performs. The benchmark was intended to uncover both the strengths and the weaknesses of a computer architecture and report them separately so that they can be understood and analyzed [GRAY91].

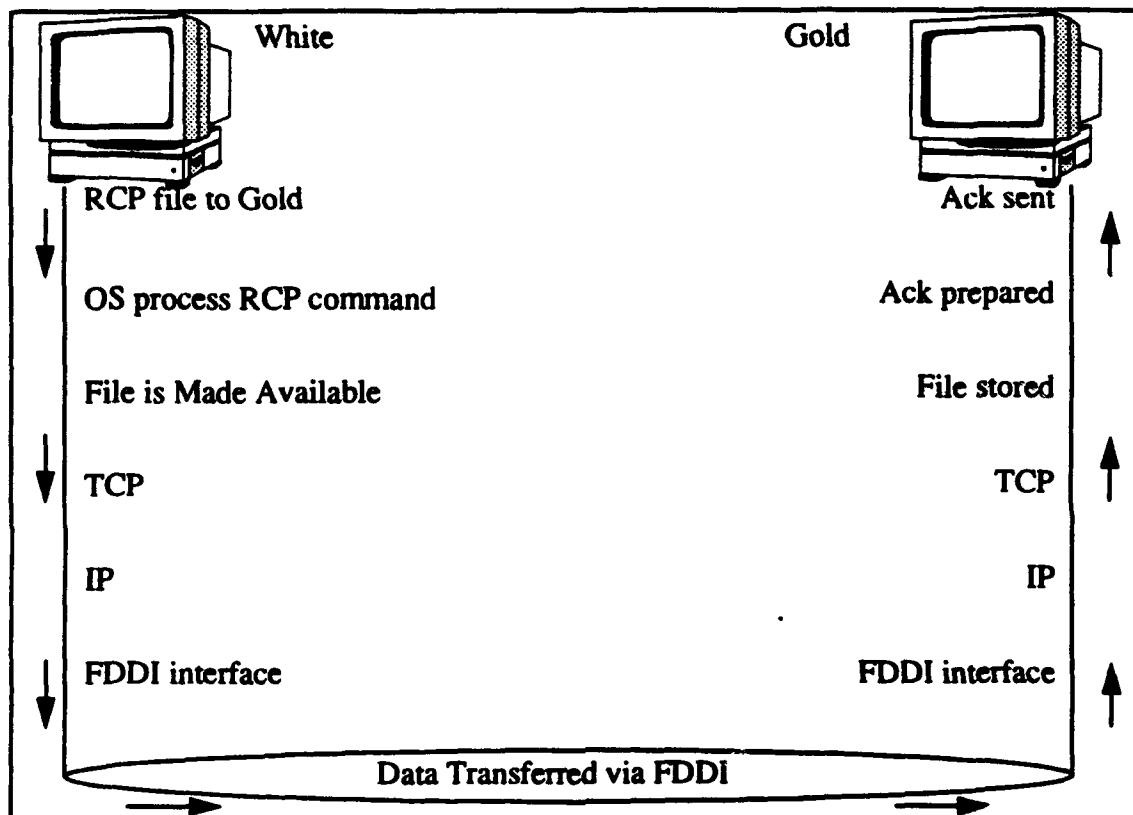


Figure 13: Flow of Data Across the FDDI Network Using the RCP Command

The Neal Nelson Business Benchmark is a multitasking benchmark with a parent/child design. A parent process creates child processes and instructs them to run tests in various combinations. There can be from one to one hundred child processes running simultaneously during a benchmark session. During a test session the parent process creates a single child process and instructs the child to perform a series of tests. Then the parent creates a second child and directs both children through the same series of tests. This

process is repeated until a desired maximum number of child processes is reached, or until the system runs out of some resource such as disk space [NNBM94].

The benchmark consists of thirty tests, which are divided into three groups.

Group 1: Tests a mix of activities that are intended to approximate the processing activities for the following five types of users. Group 1 includes the following tests:

- 1) Simulated Office Automation Workload
- 2) Simulated Database Workload
- 3) Simulated Software Development Workload
- 4) Simulated Transaction Processing Workload
- 5) Simulated Calculation Workload (Math/Statistics/CAD/CAM)

Group 2: Tests designed to perform various types of calculation tasks and thereby profile the performance of the computer's calculation subsystem. Group 2 includes the following tests:

- 6) Write to Shared Memory
- 7) Read from Memory, Small Instruction Area, Small Data Area
- 8) Read from Memory, Small Instruction Area, Larger Data Area
- 9) Read from Memory, Larger Instruction Area, Small Data Area
- 10) Read from Memory, Larger Instruction Area, Larger Data Area
- 11) Make Machine Page or Swap with 'malloc' and 'free'
- 12) Combined Integer and Floating Point Math
- 13) Math Library Functions
- 14) Semaphores, Shared Memory, Context Switch
- 15) Write to and Read from Pipes, Context Switch
- 16) Sample System Calls
- 17) Increasing Depth of Function Calls

Group 3: Tests that perform a series of disk input and output functions to profile the performance of the disk subsystem. Group 3 includes the following tests:

- 18) 1024 byte Sequential Reads from Unix File(s)
- 19) 1024 byte Sequential Writes from Unix File(s)

- 20) 8192 byte Sequential Reads from Unix File(s)
- 21) 3192 byte Sequential Writes to Unix File(s)
- 22) 4096 byte Synchronized Reads from Unix File(s)
- 23) 4096 byte Synchronized Reads from Raw Device(s)
- 24) 16384 byte Synchronized Reads from Unix File(s)
- 25) 16384 byte Synchronized Reads from Raw Device(s)
- 26) 4096 byte Pseudo Random Reads from Unix File(s)
- 27) 4096 byte Pseudo Random Reads from Raw Device(s)
- 28) Profile Disk Cache for Unix File(s)
- 29) Profile Disk Cache for Raw Device(s)
- 30) 8192 byte Sequential Writes then 'sync'

During each of the above tests, measures will be obtained at load factors from 1 to 20. This load factor number indicates the number of copies of the benchmark program which were running simultaneously. Each load factor unit might approximate the workload of one or two heavy users or possibly twenty light users. The measurements will be in seconds to complete the measured task. The system which takes less time to accomplish the measured task is the faster system.

C. NEW TEST TRANSMISSION CONTROL PROTOCOL

New Test TCP (*nttcp*) uses Test TCP (*ttcp*) as the basic tool for determining measured throughput over any physical network media. *nttcp* provides the option of dynamically changing the TCP/IP window size during the throughput test. *ttcp* was developed by the U. S. Army's Ballistic Research Lab (BRL) which is now the U. S. Army's Research Lab (ARL) and is considered one of the default network performance benchmarks.

nttcp tests TCP and UDP performance by timing the transmission and reception of data between two systems using the UDP or TCP protocols. It differs from common "blast" tests, which tend to measure the remote *inetd* as much as the network performance, and which usually do not allow measurements at the remote end of a UDP transmission.

For testing, the transmitter should be started with -t after the receiver has been started with -r. For testing various window sizes, *nttcp* allows a -w option which permits the user

to specify the desired TCP/IP window size. Some of the other options which were used during this investigation are shown below:

- t Transmit mode.
- r Receive mode.
- u Use UDP instead of TCP.
- n Number of source buffers transmitted.
- l Length of buffers in bytes.
- w TCP/IP window size in k bytes.
- p Port number to send to or listen on.

Below are the commands used in a typical session during this investigation:

Receiving system (gold):

gold: *nttcp -r -p3000 -w12*

Transmitting system (white):

white: *nttcp -t -p3000 -l65536 -n1024 -w12 gold*

The shell scripts along with the *nttcp* program are in Appendix A. The shell scripts *doit.sh* and *ttest.sh* were written by personnel at the U. S. Army Research Lab (ARL) and modified to fit this investigation. These scripts were designed to be used with the program *nttcp*. The first script, *doit.sh*, provides the various combinations of data sizes to be transferred along with starting and stopping times of each run. This script runs through six iterations of identical data sets. The shell script *ttest.sh*, provides the calls to the program *nttcp*. Using the data length and number of packets specified in the shell script *doit.sh*, *ttest.sh* makes numerous calls to *nttcp* varying the window size from 4 k to 60 k in 8 k increments. This combination of amount of data transferred, number of test runs and number of window sizes provides a total of 576 measured data transfers during a single run. Amount of data transferred (12 sizes) * number of test runs (6 runs) * number of window

sizes (8 different window sizes) = 576 measured data transfers. Below is an example of the results from a single call to *nttcp* with the amount of data to be transferred equal to 33,554,432 bytes of data and the TCP/IP window size being varied from 4 k to 60 k in 8 k increments:

Window Size(bytes)	Transfer Rate (Mb/s)
4096	32.7680
12288	29.1271
20480	37.4491
28672	43.6907
36864	52.4288
45056	43.6907
53248	43.6907
61440	37.4491

The TCP/IP window size is adjusted during these runs using the *setsockopt* system call. After the window size has been adjusted, the *getsockopt* system call is performed to verify that the TCP/IP window size has been changed as requested. Figure 14 shows an example of the *setsockopt* and *getsockopt* system calls used in the *nttcp* program.

```

if (setsockopt (fd, SOL_SOCKET, SO_SNDBUF, (char *) &sendwin, sizeof(sendwin)) < 0 )
    printf("get send window size didn't work\n");
if (setsockopt (fd, SOL_SOCKET, SO_RCVBUF, (char *) &rcvwin, sizeof(rcvwin)) < 0 )
    printf("get rcv window size didn't work\n");

if (getsockopt (fd, SOL_SOCKET, SO_RCVBUF, (char *) &sendwin, &optlen) < 0 )
    printf("get send window size didn't work\n");
else printf("send window size = %d\n", sendwin);

if (getsockopt (fd, SOL_SOCKET, SO_RCVBUF, (char *) &rcvwin, &optlen) < 0 )
    printf("get rcv window size didn't work\n");
else printf("receive window size = %d\n", rcvwin);

```

Figure 14: Example of *setsockopt* and *getsockopt* System Calls

D. REMOTE COPY PROTOCOL TRANSFER

Another program being used to measure the data transfer rate is a simple C program which issues a *rcp* command transferring a file from one workstation to another (Appendix B). The primary reason for choosing the *rcp* command is that it uses TCP which is a reliable transfer agent versus UDP which is unreliable. By using the *rcp* command, we are able to measure the time from the *rcp* command being issued to the time the *ack* is received back from the other workstation. The system can access the clock prior to issuing the *rcp* command, and then again after it receives the *ack* from the other workstation. Since the *rcp* provides for reliable data transfer, this allows a measurement of the total transfer time. Figure 15 shows the code obtaining the current system time, issuing the *rcp* command and then obtaining the system time again after the transfer is complete.

```
a = gettimeofday(&timestart, zonestart);
if (a != 0)
    printf ("Oops ! %d\n", a);

/* Use system call to do file transfer */
system ("rcp large_file gold-fddi:/usr/test/gtow_test");

/* Get stop time in sec&usec and check if successful */

b = gettimeofday(&timedone, zonedone);
if (b != 0)
    printf ("Oops! %d\n", b);
```

Figure 15: Implementation of RCP System Call

This method includes all the overhead from the operating system, *rcp*, TCP, IP and FDDI. After the *rcp* command is issued, the file is located in the file system and loaded into memory. Next, the workstation from which the command is being executed must perform a name/address resolution to determine where the file is being transferred. DNS provides this name/address resolution. Once this name/address resolution is performed the file is handed off to TCP to begin the transfer from workstation A to workstation B. TCP hands

the file transfer off to IP which forwards the file to the FDDI protocol. At this point the FDDI SBus card transfers the file from workstation A to workstation B. At workstation B the reverse scenario takes place. The file is handed off from the FDDI protocol to the IP protocol, to the TCP protocol, and finally reaches the OS on workstation B. At this point, TCP on workstation B must issue an *ack* to let workstation A know that the file has been correctly received and handed off to the OS.

The *rcp* command copies files between machines. Each filename or directory argument is either a remote file name of the form:

hostname:path

or a local file name (containing no : characters, or a / before any : characters).

If a filename is not a full path name, it is interpreted relative to the users home directory on hostname. A path on a remote host may be quoted (using \ ", or ') so that the metacharacters are interpreted remotely.

rcp does not prompt for passwords; your current local user name must exist on hostname and allow remote command execution by *rsh*.

rcp handles third party copies, where neither source nor target files are on the current machine. Hostnames may also take the form

username@hostname:filename

To use **username** rather than your current local user name as the user name on the remote host. *rcp* also supports Internet domain addressing of the remote host, so that:

username@host.domain:filename

specifies the username to be used, the hostname, and the domain in which that host resides. Filenames that are not full path names will be interpreted relative to the home directory of the user named username, on the remote host.

E. PARAMETERS WHICH AFFECT BOTH TEST

The following driver parameters will be tuned under Solaris 2.3.

```
sbf_num_llc_rx /* For LLC network traffic:  
/* Number of 4k receive buffers, maximum is 64 4k buffers  
/* Default is 48 4k buffers per NP-SB adapter  
  
nfs_async_threads /* Number of NFS thread for handling network file service  
/* Default is 8  
  
sbf_treq /* Amount of time for TTRT, default is 8ms  
/* Range is from 2ms to 165ms  
  
sbf_mtu /* Maximum protocol packet size, default is 4352 bytes
```

The above 4 tunable parameters along with the TCP/IP window size will be varied during the *rcp* and *nncp* transfer test. The TCP/IP window size controls the amount of data permitted to be transferred between TCP acknowledgments. Numerous tests will be run varying each of the four parameters to determine what combination of values provides the optimum throughput performance and what weight each parameter has on the changes. The baseline test will be the values the manufacturer recommends as the default values.

F. FILE SIZES FOR BOTH TRANSFERS

In order to measure the impact of the TCP, IP and FDDI overhead during the test, various sizes of files will be transferred. For the *rcp* test, the properties of the four files to be used are shown in TABLE 1. These files range in size from 6 bytes to 17,989,936 bytes. The amount of overhead during the transfers can be estimated as follows:

For the *nncp* test, the amounts of data to be transferred is shown in TABLE 2. The amounts of data to be transferred is obtained by specifying the length of a buffer to be transferred and the number of buffers. As an example, if 2048 buffers of length 8192 bytes

are transferred, then a total of 16,777,216 bytes of data are being transferred. The combinations listed in TABLE 2 give a range from 4,194,304 bytes to 2.684354e+08 bytes being transferred.

TABLE 1: RCP FILE SIZES AND ASSOCIATED OVERHEAD

File Size	Total Overhead
Huge (17,989,936 bytes)	1.37%
Large (1,314,923 bytes)	1.37%
Medium (48,072 bytes)	1.42%
Tiny (6 bytes)	90.9%

In order to make it easier to reference which file size has been used in the various test, the files will be referred to as File A through File H with File A being the smallest file, 4,194,304 bytes, and File H being the largest file, 268,435,400 bytes. The rest of the files are in order of size from the smallest file to the largest file.

TABLE 2: FILES (DATA SIZES) FOR NTTCP TEST

length of Buffers Number of Buffers	8192 bytes (Files A - D)	65536 bytes (Files E -H)
512	4194304 bytes	33554432 bytes
1024	8388608 bytes	67108864 bytes
2048	16777216 bytes	1.342177e+08 bytes
4096	33554432 bytes	2.684354e+08 bytes

G. SYSTEM CONFIGURATIONS FOR ALL TESTS

As described in the previous sections, various tunable parameters and file sizes will be used during this investigation. In order to obtain reliable results, numerous test must be conducted to achieve a comfortable confidence level. Unfortunately, it is not practicable to perform all the test runs necessary to test all combinations possible let alone run enough iterations of each test to obtain the desired confidence level in the results.

As an example, just running the various combinations of tests described earlier with the *nttcp* program, there were 576 measured data transfers during a single run. One such

test took a combined total of 3 hours and 15 minutes to run. During initial runs of the *nttcp* program, the TCP/IP window size was varied in 4 k increments. It was determined that there was little difference between the individual transfer rates of 4 k window sizes. Therefore, follow-on test were run at intervals of 8 k window sizes. This change reduced the run times from over 6 hours to just over 3 hours with little to no loss of usable results.

As noted earlier, there are other tunable parameters which can be modified by using the set command in the /etc/system file. Once again, it is not possible to test all possible combinations of parameters. As an example, if we start with the 576 measured data transfers which took over 6 hours with a 4 k TCP/IP window size increment, then test the TTRT parameter at 5 ms increments (33 tests), then the *sbf_num_llc_rx* buffers at 4 k increments (15 test), then the *sbf_num_smt_rx* buffers at 4 k increments (15 tests) and assume that we would like a confidence level which requires 50 runs of each test, we would have a total of $33*15*15*50 = 371250$ tests needed to reach any conclusions. If each test took over six hours to conduct, it would take a total of 2,227,500 hours or 92,812.5 days just to finish conducting the tests.

In his book [JAIN91], Raj Jain discusses this dilemma of having too many variables to consider. The solution is to first get a gross picture of the impact of changing selective parameters. Once a parameter's impact on performance has been determined, then more thorough testing can be conducted by adjusting the correct parameters to obtain the desired confidence level. An example of this method in practice is changing from 4 k intervals in the TCP/IP window size to 8 k windows sizes.

In addition to the tunable parameters already discussed, this investigation is looking into the impact of the workstations running in multiprocessor modes and using a recently developed operating system, Solaris 2.3. This now doubles the required testing! First, tests will be conducted in the two processor configuration. Then, each Sun SPARCstation will be tested with only a single process, but still running Solaris. Once again, it is not possible to test all possible tunable parameters especially in both hardware configurations. Once a pattern has been established in the single processor configuration, follow-on tests in the

multi-processor hardware configuration will be focused to limit the scope of tests to changing those parameters which produce the best results.

H. PARAMETER BASELINE

First, a baseline condition must be established before any changes are made to the system. This baseline will be with the following parameter values shown in TABLE 3. This table pertains more to the parameter settings in the *nttcp* and *rcp* test than the Neal Nelson Benchmark test. The first parameter, *NFS_asynch_threads*, has an impact on all three test. The other three parameters only impact the results of the *nttcp* and *rcp* test. No changes will be made to the workstations other than the changes to the tunable parameters listed below. Stored with the results of each *nttcp* and *rcp* test run is a README file with the below parameters and their values for that test.

While the below parameters are changed for the *nttcp* and *rcp* test, the TCP/IP window size will also be varied. The TCP/IP window size is not listed below in TABLE 3 as a tunable parameter. It is being treated differently due to the method it is varied during the test transfers. The *nttcp* program will be varying the TCP/IP window size during the test whereas the below listed tunable parameters must be changed by rebooting the workstations in-between the various tests.

TABLE 3: DEFAULT PARAMETERS USED FOR ALL THREE TEST

	<i>NFS_asynch_threads</i>	<i>t_req</i>	<i>sbf_num_llc_rx</i>	<i>sbf_mtu</i>
Neal Nelson Benchmark	8	8ms	48K	4352
<i>NTTCP</i>	8	8ms	48K	4352
<i>RCP</i>	8	8ms	48K	4352

Below is a review of the parameter descriptions:

sbf_num_llc_rx /* For LLC network traffic. Number of 4k receive buffers
/* maximum is 64 4k buffers
sbf_mtu /* Maximum protocol packet size, default is 4352 bytes
t_req /* Token holding time, default is 8ms
nfs_asynch_threads /* For NFS service. Number of threads allotted. Default is 8

The results of the initial *nttcp* baseline test during the single processor test are shown below in TABLE 4. The results shown in this table are the averaged results obtained from running this test for six runs. The first column shows the TCP/IP window size used during the test. The next 8 columns which are labeled File A through File H, show the averaged measured throughput in Mbps achieved during this test run.

TABLE 4: TEST RESULTS IN SINGLE PROCESSOR MODE

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	40.05	36.06	32.46	31.92	31.51	31.96
12	118.33	29.13	32.77	30.95	24.63	25.42	24.93	26.21
20	32.77	43.69	41.87	40.57	40.57	40.33	40.62	39.86
28	32.77	49.15	38.23	42.65	40.57	40.89	41.67	41.81
36	32.77	43.69	38.23	43.69	41.61	40.89	41.67	42.38
44	32.77	49.15	38.23	42.65	40.57	39.43	42.26	42.09
52	76.96	49.15	38.23	41.61	38.75	37.93	39.35	36.15
60	32.77	43.69	38.23	41.61	33.72	34.37	30.09	30.60

V. TEST RESULTS AND ANALYSIS

In this chapter, the results from the three tests discussed in Chapter IV will be presented. First, the results from the Neal Nelson Benchmark tests will be presented. These results will show that the newer, faster 50MHz processors should outperform the older 40MHz processors. Next, the results from the New Test TCP (*nttcp*) network throughput tests will be presented. These results will show under what conditions the highest throughput can be achieved and what throughput bottlenecks exists. Last, the results from the *rcp* transfer tests will be presented. These results will help to identify bottlenecks within the workstation as a whole. The *nttcp* tests directly access the TCP/IP layer and do not provide a true measure of all the overhead present in distributed processing.

A. NEAL NELSON BENCHMARK

The Neal Nelson Benchmark is the tool being used to measure the capabilities of the workstations and the operating systems being tested. It is important to verify that the hardware we believe will perform faster has been verified to perform faster.

To begin with, two system disks were configured with the Solaris 2.3 operating system and one system disk was configured with the SunOS 4.1.3 operating system. A three gigabyte disk was partitioned and half of it made into a Unix file system, leaving the other half as a raw disk partition. The source code for the benchmark was obtained, installed, and compiled under Solaris 2.3 and SunOS 4.1.3 with the default tuning parameters.

The benchmark was started in the background and took approximately 20 hours to run under each of the following four hardware configurations: Gold with two 50MHz processors and White with two 40MHz processors, each running Solaris 2.3; Gold with one 50MHz processor running Solaris 2.3; Gold with one 50MHz processor running SunOS 4.1.3. Solaris 2.3 is Sun Microsystem's new operating system based on AT&T System V unix while SunOS 4.1.3 is based on Berkley's unix.

Once the benchmark testing was completed, the results were collected and electronically mailed to Neal Nelson & Associates, where the test reports were generated. The results from the three different configurations discussed below are listed in Appendix C with approval from Neal Nelson & Associates.

1. Gold Versus White, Two Processors and Solaris 2.3

In group 1 tests, which are intended to approximate the processing activities of five types of users, Gold consistently performed the tasks approximately 20 percent faster than White.

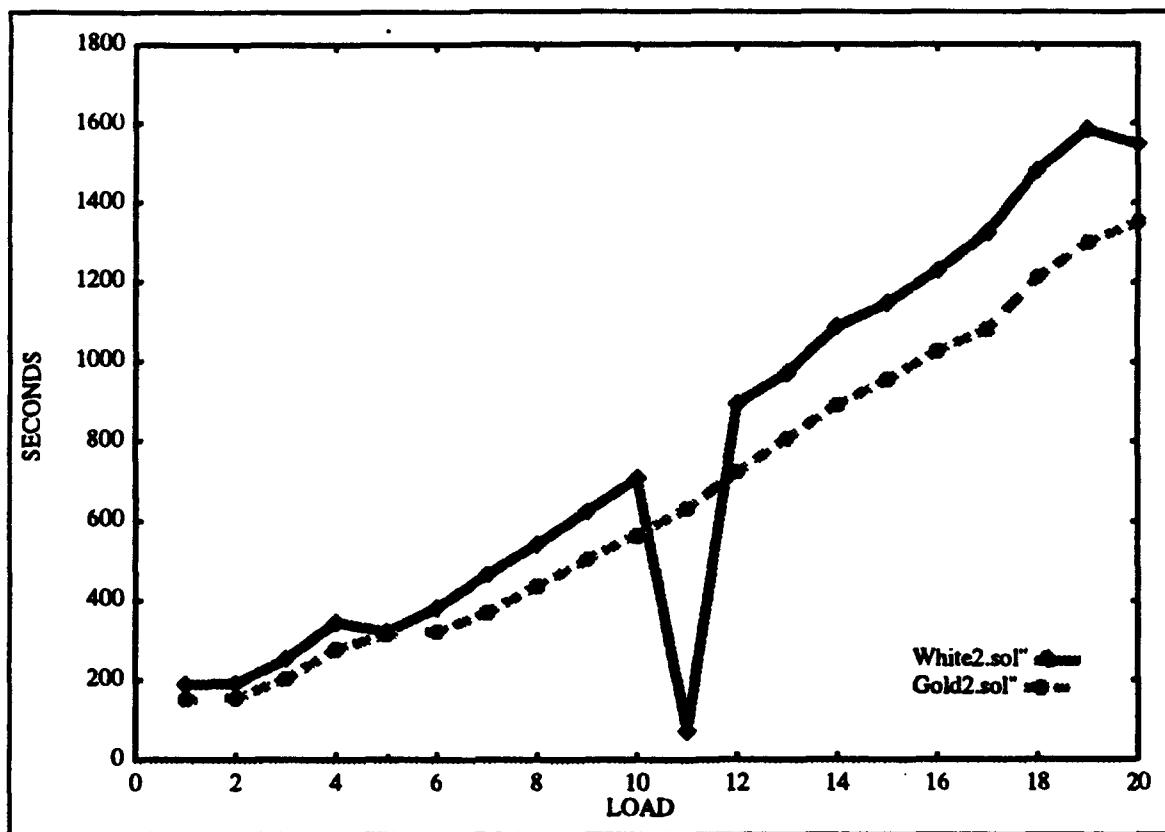


Figure 16: Gold Versus White, Two Processors

In group 2 tests, which are designed to perform various types of calculation tasks and thereby profile the performance of the computer's calculation subsystem, Gold continued to perform the tasks approximately 20 percent faster than White.

In group 3 tests, which performed a series of disk input and output functions to profile the performance of the disk subsystem, the results were mixed, but Gold still outperformed White on the average. These results varied from Gold outperforming White an average of 20 percent, to times when White outperformed Gold.

In Figure 16 on page 42 are the graphical results of Test 1, Simulated Office Automation Workload. Gold, with two 50MHz processors running Solaris 2.3, clearly took less time to perform the test than White with two 40MHz processors running Solaris 2.3 except at a load of 11. Once again, a load can signify either several light users or a single heavy user. As the loads increase you have either more light users or multiple heavy users.

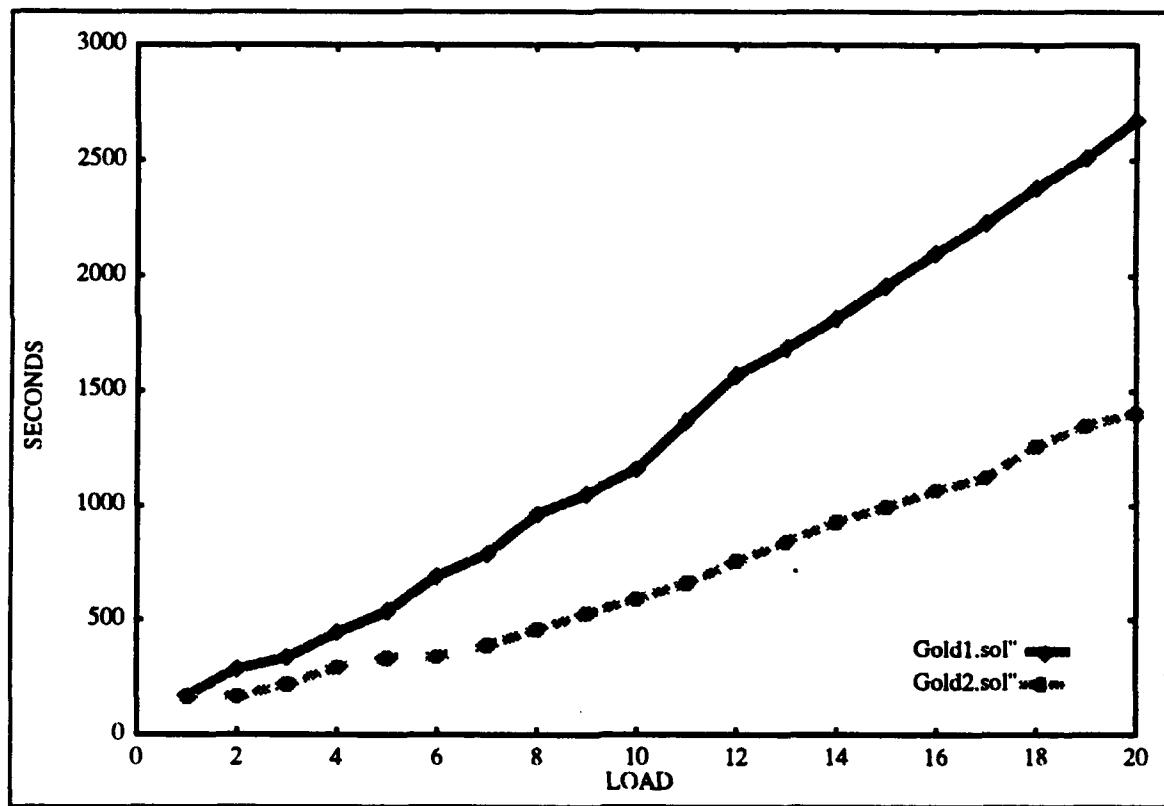


Figure 17: Gold One Processor Versus Gold Two Processors

2. Gold One Processor Versus Gold Two Processors and Solaris 2.3

In group 1 tests, the two processor configuration consistently outperformed the single processor configuration by 80 to 90 percent.

In group 2 tests, the two processor configuration continued to outperform the single processor configuration by 80 to 90 percent in all areas but one. In test 14, Semaphores, Shared Memory and Context Switch, the two processor configuration only outperformed the single processor configuration by 5 to 7 percent.

In group 3 tests, the results were once again mixed. The two processor configuration outperformed the single processor configuration in all tests but three by 50 percent. In test 19, 1024 byte Sequential Writes from Unix File(s) and test 21, 3192 byte Sequential Writes to Unix File(s), the single processor outperformed the two processor configuration by an average of over 200 percent. In test 30, 8192 byte Sequential Writes then 'sync', the single processor configuration outperformed the two processor configuration by approximately 20 percent.

In Figure 17 on page 43 are the graphical results of Test 1, Simulated Office Automation Workload. Gold with one 50MHz processor running Solaris 2.3 clearly took more time to perform the test than Gold with two 50MHz processors running Solaris 2.3.

3. Gold With One Processor, Solaris 2.3 Versus SunOS 4.1.3

In group 1 tests, the results were once again varied. SunOS 4.1.3 outperformed Solaris 2.3 in 4 of the 5 tests at the higher load levels by 3 to 4 percent. Solaris 2.3 outperformed SunOS 4.1.3 in two of the test at the lighter load levels by 3 to 4 percent.

In group 2 test, the results were more consistently in favor of SunOS 4.1.3. In 7 of the 12 test, SunOS 4.1.3 outperformed Solaris 2.3 by 4 to 5 percent. In test 13, Math Library Functions, SunOS 4.1.3 outperformed Solaris 2.3 by an average of 40 percent. Solaris 2.3 only outperformed SunOS 4.1.3 in three of the test areas. Two of the areas the percent was once again, only by 2 to 3 percent. In test 17, Increasing Depth of Function Calls, Solaris 2.3 outperformed SunOS 4.1.3 by an average of 40 to 50 percent.

In group 3 tests, the results were once again varied. In 6 of the tests, SunOS 4.1.3 outperformed Solaris 2.3 by anywhere from 15 to over 500 percent. In seven of the tests, Solaris 2.3 outperformed SunOS by anywhere from 100 to over 400 percent. Once again

though, it appears that SunOS 4.1.3 came out slightly ahead in the high load area over Solaris 2.3

Below in Figure 18 are the graphical results of Test 1, Simulated Office Automation Workload. Gold with one 50MHz processor running SunOS 4.1.3 slightly beat out Gold with one 50MHz processor running Solaris 2.3 at the higher loads.

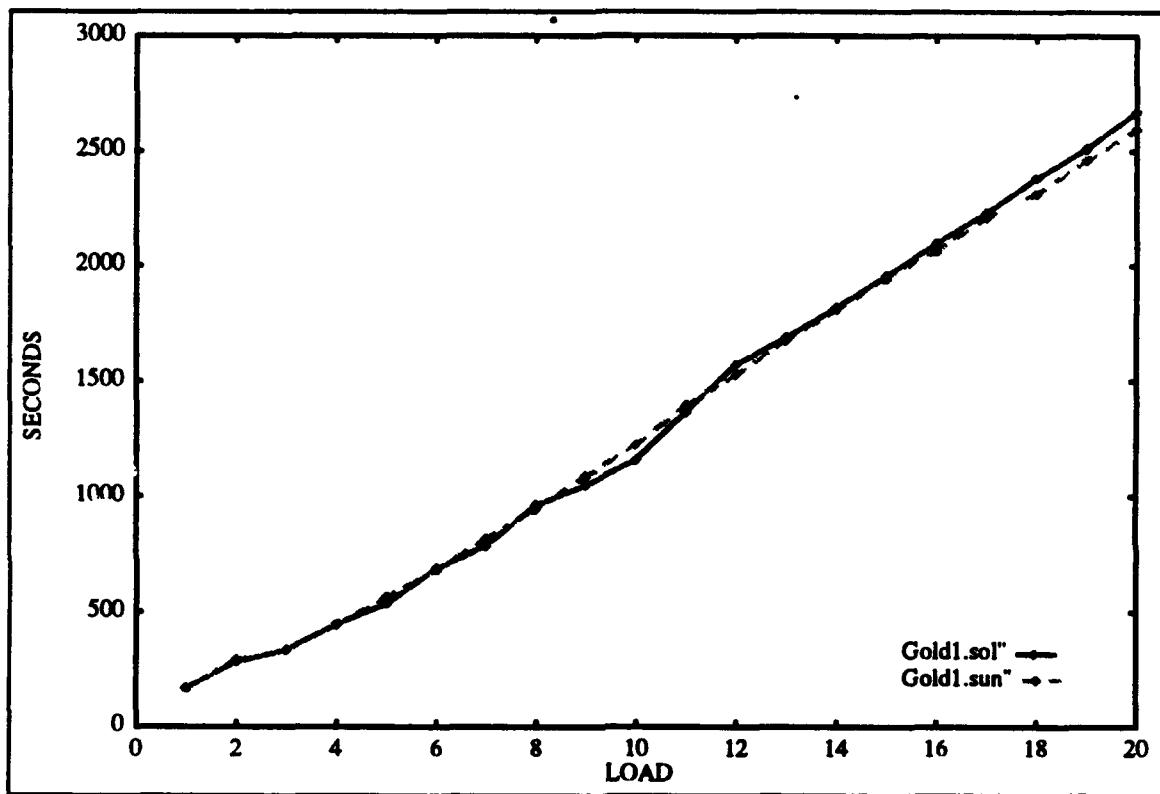


Figure 18: Gold, One Processor, SunOS 4.1.3 Versus Solaris 2.3

B. NEW TEST TRANSMISSION CONTROL PROTOCOL

As discussed in Chapter IV, the file sizes used during the test runs with New Test TCP (*nttcp*) are shown below in TABLE 5. The files are created by specifying the length of the buffer to be created and the number of buffers to be sent. The files will be referred to as File A through File H with File A being the smallest file, 4,194,304 bytes, and File H being the

largest file, 268,435,400 bytes. The rest of the files are in order of size from the smallest file to the largest file.

TABLE 5: FILES (DATA SIZES) FOR NTTCP TEST

length of Buffers Number of Buffers	8192 bytes (Files A - D)	65536 bytes (Files E - H)
512	FILE A 4194304 bytes	FILE E 33554432 bytes
1024	FILE B 8388608 bytes	FILE F 67108864 bytes
2048	FILE C 16777216 bytes	FILE G 1.342177e+08 bytes
4096	FILE D 33554432 bytes	FILE H 2.684354e+08 bytes

After conducting several test runs and observing the results, it became obvious that some smaller file sizes were not large enough to obtain accurate results. Whenever data is transferred using the *nttcp* program, the actual CPU time is the time used for calculating the throughput. If the CPU time used is too small, less than 0.1 seconds, the results become unreliable. An example of an unreliable transfer rate is given below in Figure 19. The reason for the inaccurate throughput result is the small amount of CPU time taken during this data transfer.

Transfers using the number of buffers = 512 and the length of buffer = 8192 were the only ones which had the unreliable transfer rates. There were typically only one or two transfer rates in each test which were unreliable. However, the window size was not always the same at which the unreliable transfer rate occurred. Therefore, the results of File A transfers were not used in this analysis.

```
ttcp-r: nbuf=512, buflen=8192, port=2001
send window size = 12288
receive window size = 12288
ttcp-r: 4194304 bytes in 0.06 real seconds = 68266.67 KB/sec = 546.1333 Mb/s
```

Figure 19: NTTCP Output for File Size of 4194304 Bytes

1. Single Processor Results

The first 32 test were run while Gold and White were set up in a single-processor configuration running Solaris 2.3. These 32 test represent a small subset of all possible tunable parameter combinations. The primary focus of this first set of test was to determine the effect of modifying the TCP/IP window size, the *nfs_async_threads* and the *t_req* parameters. Additionally, tests were conducted transferring data from White to Gold, Gold to White and both ways simultaneously. The 32 tests and the values of the tunable parameters are listed in TABLE 36, Appendix D.

The data gathered in the above 32 tests was analyzed using multiple linear regression analysis according to the model $y = \beta_0 + \beta_1x_1 + \beta_2x_2 + \dots + \beta_mx_m + \epsilon$ which relates the behavior of a dependent variable y to a linear function of the set of independent variables x_1, x_2, \dots, x_m . The β_j 's are the parameters that specify the nature of the relationship, and ϵ is the random error term. The dependent variable y in this model is throughput. Refer to Figure 20 on page 49 under the bold face number 12 for the list of β_j 's used in this model.

The tool used to produce the multiple linear regression analysis is Statistical Analysis System (SAS). The SAS tool is used to assist data analysts in analyzing data using regression analysis. Below in Figure 20 is an analysis of data throughput between White and Gold in the single processor configuration using the results from tests 1 - 32. Below is a description of the output from SAS as explained in [SASI91]. The bold face numbers have been added to aid in a description of the output.

1. The name of the dependent variable is THRUPUT.
2. The degrees of freedom (DF) associated with the sums of squares (SS).
3. The Regression SS (called Model SS) is 61279.61308, and the Residual SS (called ERROR SS) is 65217.01718. The sum of these two sums of squares is the C TOTAL (corrected total) SS = 126496.63026. This illustrates the basic identity in regression analysis that TOTAL SS = MODEL SS + ERROR SS. Usually, a good model results in the MODEL SS being a large fraction of the C TOTAL SS.

4. The corresponding Mean Squares are the Sum of Squares divided by the respective DF. The MS for ERROR (MSE) is an unbiased estimate of σ^2 , provided the model is correctly specified.

5. The value of the F statistic, 239.470, is the ratio of the MODEL Mean Square divided by the ERROR Mean Square. It is used to test the hypothesis that all coefficients in the model, except the intercept, are 0. In this case, this hypothesis is:

$$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5$$

6. The p value (Prob>F) of 0.0001 indicates that some of the β_i are not equal to 0.

7. Root MSE = 6.04621 is the square root of the ERROR MS and estimates the error standard deviation.

8. Dep Mean = 30.21891 is simply the average of the values of the variable THRUPUT over all observations in the data set.

9. C.V. = 20.00803 is the coefficient of variation expressed as a percentage. This measure of relative variation is the ratio of Root MSE to Dep Mean, multiplied by 100.

10. R-SQUARE = 0.4844 shows that a large portion of the variation in THRUPUT can be explained by variation in the independent variables in the model.

11. ADJ R-SQ is an alternative R-SQUARE and is an alternative to R-SQUARE that is adjusted for the number of parameters in the model according to the formula

$$\text{ADJ R-SQ} = 1 - (1 - \text{R-SQUARE})((n - 1)/(n - m - 1))$$

where n is the number of observations in the data set and m is the number of regression parameters in the model, excluding the intercept. This adjustment is used to overcome an objection to R-SQUARE as a measure of goodness of fit of the model. This objection stems from the fact that R-SQUARE can be driven to 1 simply by adding superfluous variables to the model with no real improvement in fit. This is not the case with ADJ R-SQ, which tends to stabilize to a certain value when an adequate set of variables is included in the model.

Mode: SINGLE PROCESSOR MODEL

Dependent Variable: THRUPUT

1

Analysis of Variance

Source	2 DF	3 Sum of Squares	4 Mean Square	5 F Value	6 Prob>F
Model	7	61279.61308	8754.23044	239.470	0.0001
Error	1784	65217.01718	36.55662		
C Total	1791	126496.63026			
7 Root MSE		6.0462	10 R-square	0.4844	
8 Dep Mean		30.21891	11 Adj R-sq	0.4824	
9 C.V.		20.00803			

Parameter Estimates

12 Variable	DF	13 Parameter Estimate	14 Standard Error	15 T for H0: Parameter=0	16 Prob> T
INTERCEP	1	27.673306	0.68625789	40.325	0.0001
SINGLE	1	8.620893	0.28565645	30.179	0.0001
WHITRAN	1	5.140603	0.28565645	17.996	0.0001
NUMBUFF	1	-0.000246	0.00010718	-2.295	0.0219
LENBUFF	1	-0.000107	0.00000511	-20.927	0.0001
WINDSIZE	1	0.008507	0.00779192	1.092	0.2751
TTRT	1	0.016060	0.01864409	0.861	0.3891
THREADS	1	0.008069	0.03570706	0.226	0.8212

Figure 20: SAS Analysis of Single Processor Transfers

12. The labels INTERCEP, SINGLE, WHITRAN, NUMBUFF, LENBUFF, WINDSIZE, TTRT and THREADS identify the coefficient estimates. The parameter SINGLE is used to show if the transfers were just between one workstation at a time, or if both White and Gold were transmitting at the same time. The parameter WHITRAN is used to show if White is transmitting or if Gold is transmitting. The other parameters were previously described in Chapter IV, Test Design Plan.

13. The Parameter Estimates give the fitted model

$$\begin{aligned} \text{THRUPUT} = & 27.673306 + 8.620893(\text{SINGLE}) + 5.140603(\text{WHITRAN}) \\ & - 0.000246(\text{NUMBUFF}) - 0.000107(\text{LENBUFF}) \\ & + 0.008507(\text{WINDSIZE}) + 0.016060(\text{TTRT}) + 0.008069(\text{THREADS}) \end{aligned}$$

Thus, for example, a window size of 1k contributes 0.008507 to the throughput of data if all other parameters are held fixed. If the window size is 45k, then it contributes 0.382815 if all other parameters are held fixed.

14. These are the (estimated) standard errors of the parameter estimates and are useful for constructing confidence intervals for the parameters.

15. The *t* tests (*T* for $H_0: \text{Parameter} = 0$) are used for testing hypotheses about individual parameters. The complete model for all of these *t* tests contains all the variables on the right side of the MODEL statement. The reduced model for a particular test contains all these variables except the one being tested. Thus, the *t* statistic = 0.008507(WINDSIZE) for testing the hypothesis $H_0: \beta = 0$ is actually testing whether the complete model containing NUMBUFF, LENBUFF, WINDSIZE, TTRT and THREADS fits better than the reduced model containing only NUMBUFF, LENBUFF, TTRT and THREADS.

16. The *p* value (Prob > |*T*|) for this test is *p* = 0.0001.

As shown in Figure 20 under item 16, Prob<|*T*|, the parameters NUMBUFF, WINDSIZE, TTRT and THREADS had the least impact on THRUPUT in this model. This shows up as the higher the Prob<|*T*| of the independent variable, the less impact it has on the dependent variable being modeled. Included in this model was the system transferring the data (WHITRAN) and whether it was a one way transfer or two way transfer (SINGLE). Therefore, the tunable parameters are competing with the fact that a 40MHz workstation is being compared to a 50MHz workstation and whether or not another station is competing for the token to transfer data.

The end result in this model is that the independent variable SINGLE has the most impact on THRUPUT and WHITRAN has the next largest impact on THRUPUT. This shows that competition for the token has more impact on throughput than tuning the

system. However, there is still a performance gain to be realized with tuning the system for better throughput. In Figure 21 is a graphic comparison of the 1st Test with the 29th Test. As a reminder, the 1st Test is using the default parameters and the 29th Test is using the following parameter settings: $t_req = 25\text{ms}$; $nfs_async_threads = 16$; $sbf_num_llc_rx = 48$.

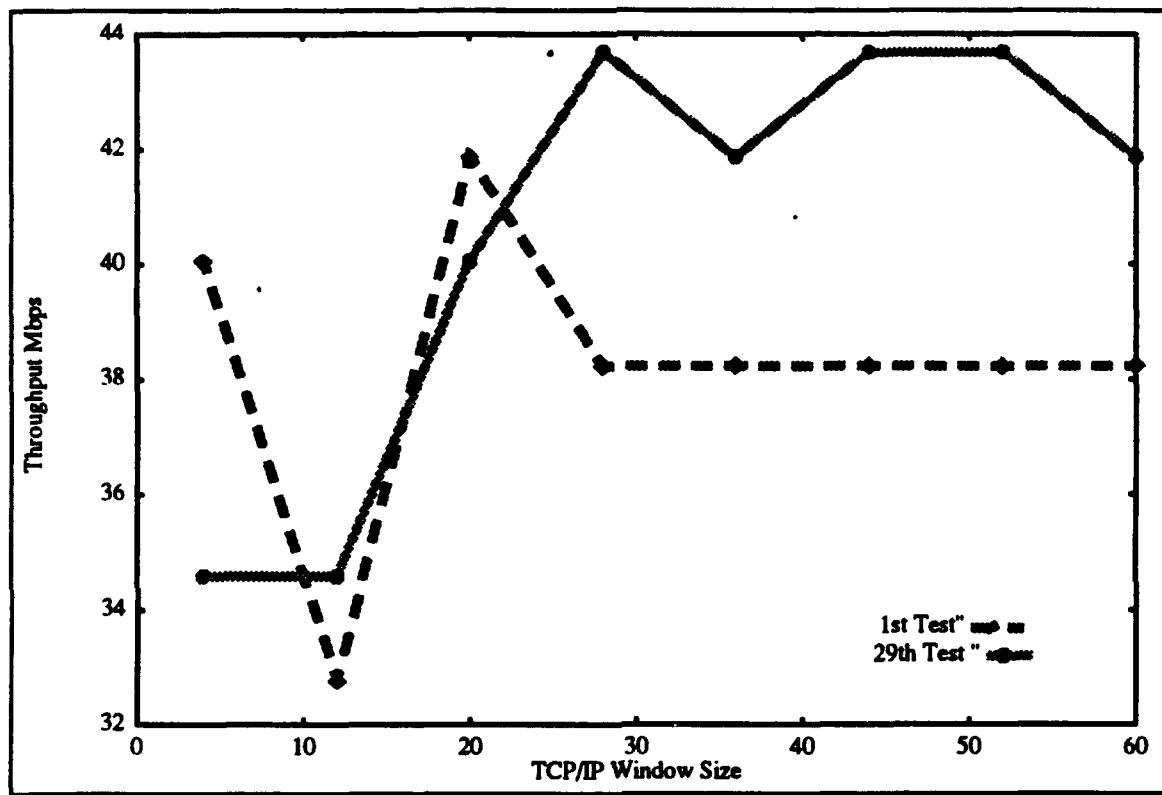


Figure 21: Single Processor, File D Transfer From White to Gold

2. Two Processor Results

The second set of test were run while Gold and White were set up in a two-processor configuration running Solaris 2.3. These 48 tests represent a small subset of all possible tunable parameter combinations. The primary focus of this set of test was to determine the effect of modifying the TCP/IP window size, the $nfs_async_threads$, t_req , $sbf_num_llc_rx$ and the sbf_mtu parameters. The 48 test and the values of the tunable parameters are listed in TABLE 71, Appendix E.

The primary difference between this set of tests and the single processor test is that all transfers were made from White to Gold. To have also included transfers from Gold to White in this set of test would have doubled the number of transfers to 96 tests. Originally it was thought that by increasing the number of parameters being observed the R-square value would also have increased. The intention here was to account for more of the factors which impact the dependent variable THRUPUT.

Mode:TWO PROCESSOR MODEL					
Dependent Variable: THRUPUT					
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	7	66901.88212	9557.41173	68.151	0.0001
Error	2680	375842.31356	140.23967		
C Total	2687	442744.19568			
Root MSE		11.84228		R-square	0.1511
Dep Mean		40.72729		Adj R-sq	0.1489
C.V.		29.07702			
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob> T
INTERCEP	1	-91.980251	12.35679655	-7.444	0.0001
NUMBUFF	1	-0.000068737	0.00017141	-0.401	0.6884
LENBUFF	1	-0.000062619	0.00000817	-7.664	0.0001
WINDSIZE	1	-0.019754	0.01246095	-1.585	0.1130
TTRT	1	-0.024980	0.02981591	-0.838	0.4022
THREADS	1	-0.034226	0.05710325	-0.599	0.5490
LLC	1	0.643378	0.03496846	18.399	0.0001
MTU	1	0.024786	0.00285516	8.681	0.0001

Figure 22: SAS Analysis of Two Processor Transfers

As shown in Figure 22 on page 52, the R-square value decreased considerably between the single processor test and the dual processor test. As it will be shown later on, the cause for this decrease was the removal of the largest impact on throughput, competing with other stations for the token. Another indicator of the lack of confidence in the data being modeled is the large Standard Error for the independent variable INTERCEP. In the single processor model INTERCEP had a value of 0.68625789. In the dual processor model, the error has increased to 12.35679655.

The independent variables, NUMBUFF, THREADS and TTRT continued to have the least amount of impact on the dependent variable THRUPUT as indicated by their low Prob>ITI values. The independent variables with the largest impact were LENBUFF, LLC and MTU.

3. One And Two Processor Results

In the final analysis of both one and two processor tests, some additional facts need to be presented. There were a total of 4,480 throughputs measured in this analysis. There were 896 measurements in the one processor configuration and 2688 measurements in the two processor configuration. These are averaged measurements taken from the six runs in each $32 + 48 = 80$ tests. Also, there were 896 measurements where both Gold and White were transmitting at the same time and 2688 measurements where only one station was transmitting.

When the model was first run including all the data from the one and two processor tests the R-square value was only 0.3559. This was higher than in the two processor model but lower than in the one processor model. A scatter plot was made of the various parameters to determine where there might be some problems with individual parameters. The most obvious problem was seen with the large variation of throughput with the parameter window size. At both the high end and the low end, the plot of window size versus throughput was not linear. By restricting the analysis of data to window sizes less

than 50k and greater than 16k the R-square value increased to 0.6600. This reduced the number of measured observations from 4,480 throughputs to 2,240 measured throughputs.

Mode: ONE & TWO PROCESSOR MODEL					
Dependent Variable: THRUPUT					
Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	10	179959.58511	17995.95851	432.681	0.0001
Error	2229	92708.03657	41.59176		
C Total	2239	272667.62168			
Root MSE		6.44917	R-square	0.6600	
Dep Mean		42.53933	Adj R-sq	0.6585	
C.V.		15.16048			
Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob> T
INTERCEP	1	-70.427345	9.87019489	-7.135	0.0001
SINGLE	1	9.928996	0.43090313	23.042	0.0001
WHTRAN	1	3.652165	0.43090313	8.476	0.0001
NUMBUFF	1	-0.000052070	0.00010226	-0.509	0.6107
LENBUFF	1	-0.000047372	0.00000487	-9.719	0.0001
WINDSIZE	1	-0.200113	0.01523473	-13.135	0.0001
TTRT	1	-0.012831	0.01778717	-0.721	0.4708
THREADS	1	-0.039099	0.03406588	-1.148	0.2512
LLC	1	0.583336	0.02693145	21.660	0.0001
MTU	1	0.015782	0.00219894	7.177	0.0001
SD	1	9.535964	0.44849820	21.262	0.0001

Figure 23: SAS Analysis of Single and Two Processor Transfers

The results of the one and two processor analysis are above in Figure 23. One new independent variable, SD is used to model whether the transfer comes from the one processor tests or the two processor tests. Just as before, the independent variables

NUMBUFF, TTRT, and THREADS have the least amount of impact on THRUPUT. With the removal of the window sizes noted above, WINDSIZE now carries more weight in this model. The largest impact on THRUPUT in order of impact is caused by the variables SINGLE, SD, LLC and WINDSIZE. This statement will be covered in more detail later. This indicates once again that processor power has the largest impact on throughput. A graphical model of the difference is below in Figure 24. In this figure are plots of throughput from identical parameter configurations, but one is from a two processor run and the other is from a one processor run.

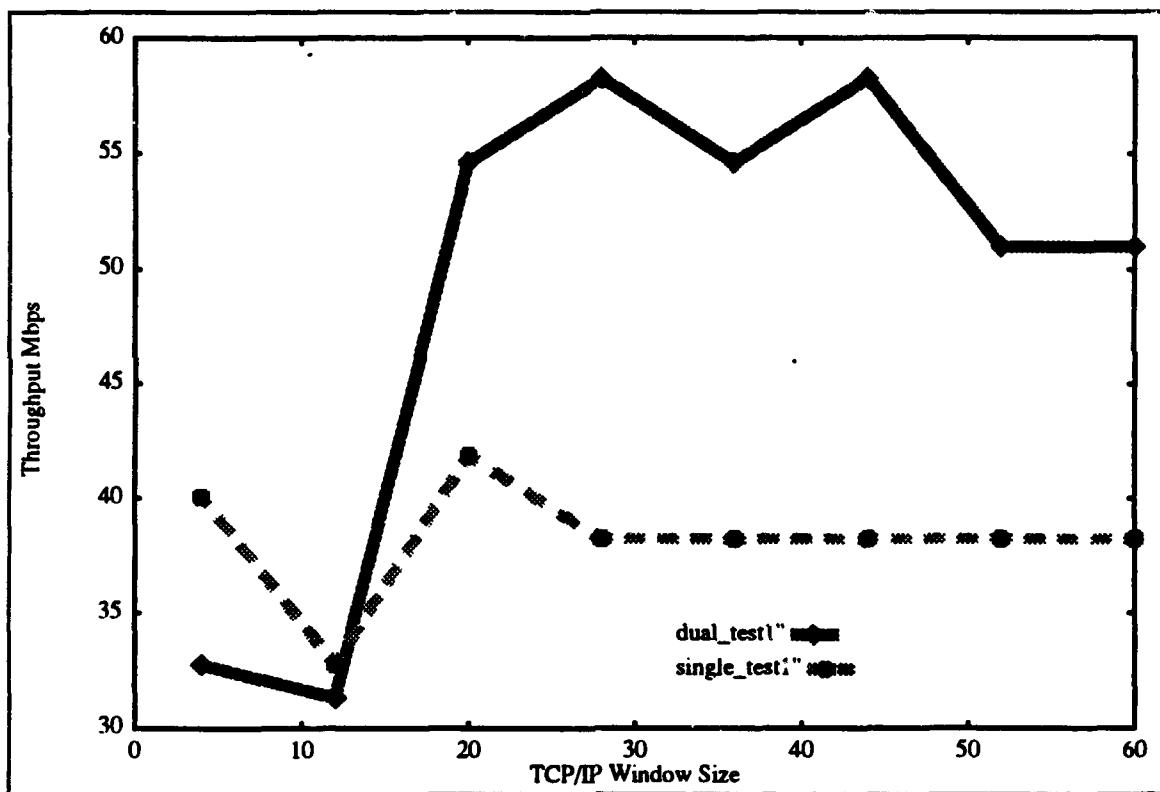


Figure 24: White Single Processor vrs White Two Processors

Another useful result which can be determined from the analysis of the one and two processor tests is a predicted throughput. Below in Figure 25 are SAS predictions of THRUPUT based on the 2,240 measured throughputs used in this analysis. To achieve the minimum predicted throughput, the following test was run using the parameter settings

indicated in Figure 25. Data was transferred from Gold to White and White to Gold simultaneously. The results were taken from Gold with NUMBUFF = 4096, LENBUFF = 65536, WINDSIZE = 44, TTTRT = 25, THREADS = 16, LLC = 40 and MTU = 4192. The results are below in TABLE 6.

The SAS predictions for the minimum predicted throughput was for a rate of 15.5302 Mbps. As shown in TABLE 6 the results from the actual tests was an average of 15.1463 Mbps and an mean of 15.0454 Mbps. Since the data used in the model was averaged data instead of mean data, the averaged achieved rate is the more accurate throughput rate to use. The SAS predictions for the maximum predicted throughput was for a rate of 58.7810 Mbps. As shown in TABLE 6 the results from the actual tests was an average of 60.07 Mbps and an mean of 65.5360 Mbps. In both cases the average throughput measured was very close to the predicted throughput. This shows that the SAS model was very accurate

W											
S	H	U	E	N	H	R		T	H	R	
I	I	M	N	D	T	E		A		U	
N	T	B	B	S	T	E		L	M	S	P
O	G	R	U	U	I	T		D	L	T	U
B	L	A	F	F	Z	R		D	L	D	
S	E	N	F	F	E	T		S	C	U	T
1	1	1	1024	8192	20	5	8	56	4352	2	58.7544
2	0	0	4096	65536	44	25	16	40	4192	1	15.5302

Figure 25: SAS Throughput Prediction

TABLE 6: RESULTS OF SAS PREDICTIONS

PREDICTION	RUN1	RUN2	RUN3	RUN4	RUN5	RUN6	AVG	MEAN
LOW	17.4763	16.3840	12.8660	13.7069	20.1649	10.2802	15.1463	15.0454
HIGH	32.7680	65.5360	65.5360	65.5360	65.5360	65.5360	60.07	65.5360

The following formula relates the behavior of the dependent variable THRUPUT to a linear function of the set of independent variables SINGLE, WHITRAN, NUMBUFF, LENBUFF, WINDSIZE, TTTRT, THREADS, LLC, MTU and SD. These are the values calculated in the One and Two Processor Model, Figure 23 on page 54.

$$\begin{aligned} \text{THRUPUT} = & -70.427345 + 9.928996(\text{SINGLE}) + 3.652165(\text{WHITRAN}) \\ & - 0.000052070(\text{NUMBUFF}) - 0.000047372(\text{LENBUFF}) \\ & - 0.200113(\text{WINDSIZE}) - 0.012831(\text{TTTRT}) - 0.039099(\text{THREADS}) \\ & + 0.583336(\text{LLC}) + 0.015782(\text{MTU}) + 9.535964(\text{SD}) \end{aligned}$$

When the minimum and maximum throughput was predicted above in Figure 25 on page 56, it was simply a matter of inserting the largest parameter value in the above formula . the parameter estimate is positive and the smallest parameter value if the parameter estimate is negative. This resulted in the maximum predicted throughput. For the minimum predicted throughput, the largest parameter value is used if the parameter estimate is negative and the smallest parameter value if the parameter estimate is positive.

Below are the formulas for minimum and maximum throughput with the parameter estimates and parameter values multiplied together.

Maximum Throughput:

$$\begin{aligned} 58.7544 = & -70.427345 + 9.928996 + 3.652165 - 0.05331968 - 0.38807142 - 4.00226 \\ & - 0.064155 - 0.312792 + 32.666816 + 68.683264 + 19.071928 \end{aligned}$$

Minimum Throughput

$$\begin{aligned} 15.5302 = & -70.42734 + 0 + 0 - 0.21327872 - 3.1045714 - 8.804972 - 0.320775 \\ & - 0.625584 + 23.33344 + 66.158144 + 9.535964 \end{aligned}$$

Once the minimum and maximum throughputs were computed, the relative value of each parameter was calculated by subtracting the parameter's minimum value from it's maximum value. Below in Figure 26 are the results from this calculation. The value from the maximum calculation is listed, then the value from the minimum value is listed and

finally the difference is listed. It is this difference which shows the impact each parameter has on the end throughput. The higher the difference is, the more weight that parameter carries in determining the maximum throughput.

W										
S	W	N	L	I		T	H			
I	H	U	E	N		R				
N	T	B	B	S	T	E				
G	R	U	U	I	T	A	L	M	S	
L	A	F	F	Z	R	D	L	T	D	
E	N	F	F	E	T	S	C	U		
MAX:	9.92	3.65	-0.05	-0.38	-4.00	-0.06	-0.31	32.66	68.68	19.07
MIN:	0	0	-0.21	-3.10	-8.80	-0.32	-0.62	23.33	66.15	9.53
DIFF:	9.92	3.65	0.16	2.72	4.8	0.26	0.31	9.33	2.53	9.54

Figure 26: Relative Importance of Each *nttcp* Parameter

The results listed above show that the following parameters, in order of importance, have the most impact on throughput using the current model:

- If the data was only being transferred from one workstation to another or if both workstations were transferring data to each other simultaneously.
- Whether the workstation had one or two processors
- The number of 4K receive buffers allotted for receiving data.
- The number of TCP/IP windows available for sending data.

Since the TCP/IP window size was limited in the above model to a range of 20k to 44k, this parameter showed up having less of an impact than it really has. As an example, in TABLE 72 on page 120 of Appendix E, the throughput rate for File C is 32.77 Mbps for a window size of 4k and 58.25 Mbps for a window size of 44k. That means the throughput rate at a 4k window size is only 56 percent the rate of the 44k window size. In this case, the window size has the largest impact on throughput performance. Unfortunately though, the results at the lower and higher window sizes were not consistent in all cases and the data was removed from the analysis. In most cases though, the difference in throughput

performance between a TCP/IP window size of 4k and a window size of greater than 20k is more significant than any other factor considered in this investigation.

Based on the visual inspection of the results from both the one processor tests and the two processor tests, below is a revised list in order of importance the parameters having the most impact on throughput:

- The number of TCP/IP windows available for sending data.
- If the data was only being transferred from one workstation to another or if both workstations were transferring data to each other simultaneously.
- Whether the workstation had one or two processors
- The number of 4K receive buffers allotted for receiving data.

Another parameter which showed unexpected results is the WHITRAN parameter. This parameter is used to track any differences in throughput between transmitting data from White to Gold, or from Gold to White. The result in Figure 25 on page 56 indicates that transmitting data from White to Gold was faster than transmitting data from Gold to White. In the first 32 one processor tests, White had one 40MHz processor and Gold had one 50MHz processor. In the second 48 tests, White had two 40MHz processors and Gold had two 50MHz processors. Based on the Neal Nelson Benchmark tests, Gold should be capable of transferring data faster than White.

Several additional tests were conducted to determine why White was able to transmit data at a higher throughput than Gold. First, the FDDI cards were swapped to see if the FDDI card in Gold was causing the problem. The results of these tests are in TABLE 69 on page 117 and TABLE 70 on page 118. There was not any noticeable difference in throughput rates with the boards swapped. Next, the two 50MHz processors were placed in White and the two 40MHz processors were placed in Gold. The results of these tests are in TABLE 121 and TABLE 122 on page 137. As shown in Figure 27, even when both transmitting systems had two 50MHz processors and both receiving systems had 40MHz processors, White still had a higher throughput rate with File C than Gold.

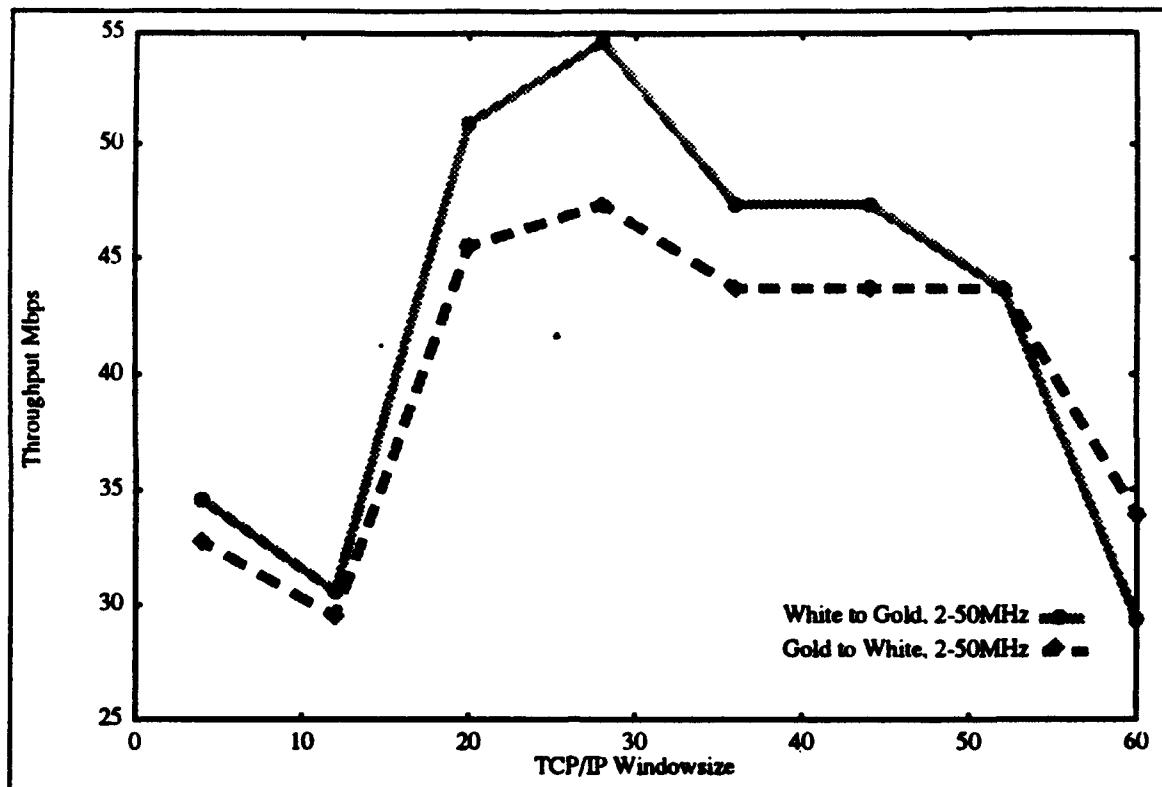


Figure 27: Throughput Comparison Between White and Gold

The only other difference between White and Gold is that Gold is the server on the FDDI network. Since the FDDI network only had three workstations on the network, this additional load on Gold should not be that great.

C. REMOTE COPY PROTOCOL TRANSFERS

Initially, the plan was to conduct file transfers using the *rcp* system call varying the tunable parameters just as in the *nttcp* tests. However, it was quickly observed that there were not any noticeable differences in measured throughput at the different parameter settings. This was understandable with the parameters *nfs_async_threads* and *t_req*. The SAS model showed that these tunable parameters had little effect on throughput. However, it was expected that there would be some different throughput rates with the TCP/IP window size, *llc* and *mtu* parameters varied.

The reason why these parameters did not have an impact was that *rcp* does small size *read()*'s and *write()*'s, so the syscall overhead dominates over the time spent in the kernel in TCP. If an application wants optimum bulk data throughput, it should increase the receive buffering, and also do moderately large *read()*'s and *write()*'s so that the syscall overhead does not dominate. Also, *rcp* has to go through a complete login, exec of the user's shell, and run through the user's ".cshrc" or ".profile" on the server side before it begins transferring any data. If the data transfer is not really huge, the time spent logging in will be much greater than the time spent transferring the data.

Knowing that the largest impact on throughput based on the SAS modeled data is TCP/IP window size, processor power and whether or not another station is also transmitting, four different transfer tests were conducted with each of the four file sizes. As shown below in TABLE 7 and TABLE 8 on page 62, tests were conducted in the one processor configuration and the two processor configuration while transferring files one-way and two-way (between White and Gold simultaneously).

TABLE 7: RCP ONE PROCESSOR TRANSFER RESULTS

	TINY (6 bytes)	MEDIUM (48,072 bytes)	LARGE (1,314,923 bytes)	HUGE (17,989,936 bytes)
ONE-WAY TRANSFER White to Gold				
TO: /FILE-NAME	.000032 Mbps	.25 Mbps	4.91 Mbps	13.20 Mbps
TO: /DEV/NULL	.000032 Mbps	.25 Mbps	5.85 Mbps	26.41 Mbps
TWO-WAY TRANSFERS White to Gold & Gold to White				
TO: /FILE-NAME	.000027 Mbps	.23 Mbps	4.47 Mbps	11.49 Mbps
TO: /DEV/NULL	.000027 Mbps	.22 Mbps	4.73 Mbps	16.72 Mbps

Also, files were transferred from disk to disk and from disk to /dev/null. This second transfer method does not result in a disk write at the destination workstation. The device driver, /dev/null, is used to dispose of files without needing to delete them. Files can be sent to /dev/null and this device driver accepts the data without writing them to disk.

The largest impact seen in this set of tests was the file size. The lowest throughput rate was observed when transferring the smallest file, TINY. This file has an associated overhead of 90.9% when being transferred over FDDI. The highest throughput was seen with the file HUGE. This file only had an overhead of 1.37% when transferred over FDDI. These overhead figures include the overhead associated with the FDDI, IP and TCP protocols. Another area with similar results as the *nttcp* test is whether the transfers are one-way or two-way. When the two workstations have to compete for the token the throughput drops.

TABLE 8: RCP TWO PROCESSOR TRANSFER RESULTS

	TINY (6 bytes)	MEDIUM (48,072 bytes)	LARGE (1,314,923 bytes)	HUGE (17,989,936 bytes)
ONE-WAY TRANSFER White to Gold				
TO: /FILE-NAME	.000031 Mbps	.25 Mbps	4.94 Mbps	13.54 Mbps
TO: /DEV/NULL	.000031 Mbps	.25 Mbps	5.87 Mbps	28.42 Mbps
ONE-WAY TRANSFER Gold to White				
TO: /FILE-NAME	.000029 Mbps	.24 Mbps	5.26 Mbps	21.66 Mbps
TO: /DEV/NULL	.000029 Mbps	.24 Mbps	5.81 Mbps	29.82 Mbps
TWO-WAY TRANSFERS White to Gold & Gold to White				
TO: /FILE-NAME	.000029 Mbps	.24 Mbps	4.64 Mbps	13.27 Mbps
TO: /DEV/NULL	.000030 Mbps	.24 Mbps	5.55 Mbps	23.18 Mbps

The results during the *rcp* tests were much lower than during the *nttcp* tests. As an example, on the transfer of a file size of over 17 Mbytes from Gold with two processors to White:/dev/null, the best achieved throughput rate was 29.82 Mbps with *rcp*. This is only 29.82 percent of FDDI's available bandwidth and only 43.7 percent of the highest achieved throughput using *nttcp* (65Mbps). When transferring the same file from Gold to White and writing the file to disk, the transfer rate was 21.66 Mbps. This rate is only 72 percent of the transfer rate of transferring the data to /dev/null. Below in Figure 28 on page 63 is a

graphical plot of the transfer rates just mentioned while transferring the 17.9 Mbyte file from Gold with two 50MHz processors to White with two 40 MHz processors.

There were two main differences between the transfer methods: First, the *rcp* transfers add another layer of protocols to the transfers. The *rcp* protocol hands off the data to be transferred to the TCP/IP protocol layers. This of course increases the amount of overhead transferred. Second, using *rcp* to transfer the data involves reading the data from disk before it can be transferred. Even though large amounts of data can be cached in the SuperCache 1-Mbyte external cache, this is not large enough for extremely large files being transferred to be completely cached. During this test files were transferred 9 times and then the median throughput rate was used for the results.

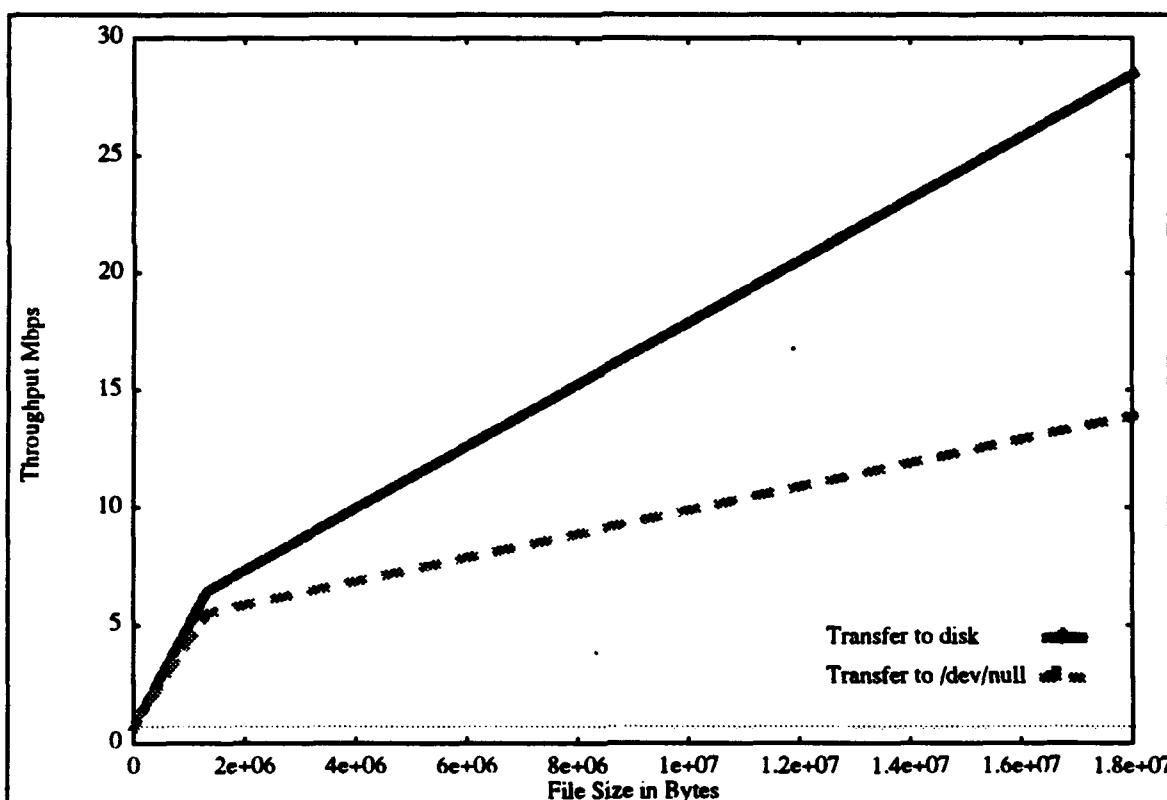


Figure 28: RCP File Transfers From Gold To White

The results from the *rcp* tests were pretty much as expected. The two processor transfers were faster than the single processor transfers and the one-way transfers were

faster than the two-way transfers. However, the difference in these throughput rates was not as large as that seen with the *nttcp* tests. Since the additional overhead from the *rcp* system call should affect the transfer rates evenly, then the only other difference is that the data was transferred from disk instead of being generated by the CPU. The large difference in throughput rates achieved between the two test methods would indicate that the disk access is a very large bottle neck in throughput performance.

A quick comparison of the throughput rate observed using *nttcp* for a file size of 16,777,216 bytes (File C) and a *rcp* transfer of a file size 17,989,936 bytes shows a throughput rate of 32.77 Mbps for the *nttcp* transfer and a throughput rate of 28.42 Mbps when transferred to /dev/null. Both of these tests were one-way tests from White to Gold with both systems in the two processor configuration. In this comparison, the *rcp* tests had a throughput rate which is 86.7 percent of the *nttcp* throughput rate. This seems to indicate that the retrieval of the file from disk and the overhead of the *rcp* protocol are responsible for 13.7 percent of the slow down in throughput when transferring files.

When comparing the transfer rate of an *rcp* transfer from White to a file location on Gold with the *nttcp* throughput rate, there is a much larger difference in throughput. The *nttcp* throughput rate is still 32.77 Mbps and the throughput rate for the *rcp* file to file transfer is 13.54 Mbps. Here the *rcp* throughput rate is 41.3 percent of the *nttcp* throughput rate. This means that the time to receive and process the file at the destination workstation accounts for 45 percent of the reduced throughput. This is the 58.7 percent reduction minus the 13.7 percent attributed to the retrieval of the file from disk and the overhead of the *rcp* protocol.

D. ANALYSIS SUMMARY

The results from the Neal Nelson Benchmark showed that the systems being investigated were functioning as expected. The 50MHz system outperformed the 40MHz system and the two processor system outperformed the one processor system. One

unexpected result was that SunOS 4.1.3 slightly outperformed Solaris 2.3 in just about every test except disk access to unix files. Solaris 2.3 was the clear winner in this area.

The *nttcp* results were analyzed using a linear multiple regression analysis model. Even though the throughput results were not linear, the model is believed to be accurate enough to show the relationship between the parameters being investigated. The analysis of this data provides the most concrete results of the two throughput tests methods.

The number of workstations on an FDDI network transmitting has the largest impact on throughput among the parameters investigated according to the one processor and two processor models. An example of this impact is to take the SAS prediction shown in Figure 25 on page 56 and change the parameter SINGLE from its one-way value to the two-way value. This allows SAS to predict a new throughput rate based on all the previous values except the change just noted. The result of the new prediction shows a new throughput prediction of 48.8254 Mbps. This is only 83.1 percent of the original throughput predication of 58.7544 Mbps.

The power of the workstation itself is a major factor in throughput potential. This is seen in the fact that the second largest impact on throughput in the one processor and two processor model is whether or not the workstation had two processors. The result of the new one processor prediction shows a throughput predication of 49.2184 Mbps. This is 83.7 percent of the original throughput predication of 58.7544 Mbps.

Since the TCP/IP window size was limited in the model to a range of 20k to 44k, this parameter showed up having less of an impact than it really has. In most cases though, the difference in throughput performance between a TCP/IP window size of 4k and a window size of greater than 20k is more significant than any other factor considered in this investigation.

The results from the *rcp* tests are more of an observation of the effects of the disk drive on throughput performance. Since both tests measure the time from start of test to receiving the *ack* from TCP on the receiving workstation that the data has been received, the only

other real differences is the *rcp* protocol and the fact that the data is being transferred as files instead of being generated by the processor.

As pointed out earlier, the overhead of the *rcp* protocol and the time spent retrieving the file from disk is approximately 13.7 percent of the throughput rate observed during the *nttcp* throughput tests. Additionally, the overhead of processing the file at the receiving workstation is approximately 45 percent of the throughput rate observed during the *nttcp* throughput tests.

The observation made in the *nttcp* tests that white with only 40MHz processors could transfer data faster than Gold with 50MHz processors was not seen again in the *rcp* tests. In the *rcp* tests, Gold was able to transfer data at a higher throughput rate than White when Gold had the two 50MHz processors and White had the two 40MHz processors.

VI. CONCLUSIONS AND TOPICS FOR FUTURE RESEARCH

A. CONCLUSION

The objective of this research was to measure actual throughput between high performance workstations over an FDDI network to determine what bottlenecks, if any, exists between Sun Microsystem SPARC 10 multiprocessors running the Solaris 2.3 and Network Peripheral Inc.'s (NPI) FDDI network interface cards and to evaluate Transmission Control Protocol/Internet Protocol (TCP/IP) as a high speed transport protocol.

At the beginning of this investigation there were many speculations as to what throughput rates could be achieved and what effect varying the different tunable parameters would have on the throughput rates. It was assumed that the workstation with the 50MHz processor would have a faster throughput rate than the workstation with the 40MHz processors. It was also assumed that since Sun Microsystems was encouraging their users to switch from SunOS to Solaris, that Solaris 2.3 would clearly out perform SunOS 4.1.3.

The following sections outline the conclusions drawn from these investigations:

1. Workstation Conclusions

There were four benchmark tests conducted using the Neal Nelson Business Benchmark run on the two workstations, Gold and White.

- Gold had two 50MHz processors installed and was running Solaris 2.3.
- Gold had one 50MHz processor installed and was running Solaris 2.3.
- Gold had one 50MHz processor installed and was running SunOS 4.1.3.
- White had two 40MHz processors installed and was running Solaris 2.3.

Three test comparisons were conducted by Neal Nelson and Associates and the results can be summarized as follows:

- A workstation running Solaris 2.3 with two 50MHz processors can be expected to outperform a workstation running Solaris 2.3 with two 40MHz processors

in most areas of performance by approximately 20 percent.

- A workstation running Solaris 2.3 with two 50MHz processors can be expected to outperform a workstation running Solaris 2.3 with one 50MHz processor in most areas of performance by approximately 90 percent.
- A workstation running SunOS 4.1.3 with one 50MHz processor can be expected to outperform a workstation running Solaris 2.3 with one 50MHz processor in most areas of performance by approximately 2 percent.

Of the three comparisons noted above, the first two results were expected. However, it was assumed that Sun Microsystem's release of Solaris 2.3 would result in improved operating system performance, not a slight drop in performance. These results were very important in the next step of the investigation. Knowing that the workstation with two 50MHz processors should outperform the workstation with two 40MHz processors helped isolate some unexpected results in workstation throughput.

2. Throughput Conclusions

There were two methods used in this investigation to measure throughput. First, a public domain network throughput measurement tool, New Test TCP (*nttcp*), was used in order to minimize the workstation overhead. Next, the Remote Copy Protocol (*rcp*) system call was used in order to include all the overhead of daily distributed processing. The results obtained from these two test methods were consistent with each other.

New Test TCP (*nttcp*): During the *nttcp* tests the following tunable parameters were varied to determine their impact on throughput performance:

- TCP/IP window size, the amount of data that can be in transient at any one time between workstations.
- *sbf_num_llc_rx*, number of receive buffers (4k each) on the FDDI board allotted for receiving data.
- *nfs_async_threads*, number of asynchronous threads allotted for handling network file system service.
- *sbf_treq*, amount of time allotted for each workstation to transfer data prior to passing on the token. This is the TTRT.
- *sbf_mtu*, maximum protocol packet size.

Additionally, the *nttcp* tests were run on both single processor configurations and on two processor configurations. During this investigation the *nttcp* tests results showed that the four most significant impacts on throughput and the order of impact were as follows:

- Whether data was being transferred one-way or if both workstations were transferring data simultaneously.
- Whether the workstation had one or two processors
- The number of 4K receive buffers allotted for receiving data.
- The size of TCP/IP window available for sending data.

One note about the TCP/IP window size. During this investigation TCP/IP window sizes less than 20k and greater than 44k had too large of a deviation in their throughput results to be included in the final analysis. When all of the TCP/IP window sizes are included, this parameter ends up having the largest impact on throughput rates. The rest of the results retain the above order of impact on throughput.

The other tunable parameters varied during these tests had little impact on throughput performance. Below are the rest of the factors affecting throughput in their order of importance:

- The length of the buffers being transmitted. This equates to the size of the data being transmitted.
- The Maximum Transmission Unit (MTU) size. This is the size of the FDDI frames of data being transmitted.
- The number of NFS asynchronous threads allowed for servicing network file service.
- The number of buffers (file size) being transmitted.

Remote Copy Protocol (*rcp*): During the *rcp* tests the tunable parameters were varied, but there was no noticeable difference in these throughput rates. The TCP/IP window size, which had the largest impact in the *nttcp* tests, did not have any noticeable impact on throughput. The reason why the TCP/IP window did not have an impact was that *rcp* does small size read()'s and write()'s, so the all overhead dominates over the time spent in the kernel in TCP. If an application wants optimum bulk data throughput, it should

increase the receive buffering, and also do moderately large `read()`'s and `write()`'s so that the syscall overhead does not dominate.

The only difference between the *nttcp* tests and the *rcp* tests was the additional overhead with the *rcp* disk transfers and the *rcp* protocol overhead. Therefore, the conclusion can be drawn that one of these two differences accounted for the very large drop in throughput between the *nttcp* tests and the *rcp* tests.

On the transfer of a file size of over 17 Mbytes from White with two processors to Gold, the best achieved throughput rate was 13.54 Mbps with *rcp* when the transferred data is written to disk. This is only 13.54 percent of FDDI's available bandwidth and only 41.3 percent of the highest achieved throughput using *nttcp* at the same TCP/IP window size of 8k. Most of this 41.3 percent difference between *rcp* and *nttcp* can be attributed to the *rcp* protocol overhead. *RCP* has to go through a complete login, exec of the user's shell, and run through the user's ".cshrc" or ".profile" on the server side before it begins transferring any data. If the data transfer is not really huge, the time spent logging in will be much greater than the time spent transferring the data.

B. TOPICS FOR FUTURE RESEARCH

Several topics for further study can be derived from this investigation. All of them are related to either improving throughput or to explaining events which were not explained in this thesis.

Since the *nttcp* tests were only able to obtain a maximum throughput using TCP transfers of 65 Mbps, 35 percent of the available bandwidth of FDDI is not being used. What portion of this unused bandwidth is due to lack of processor power and what portion is due to inefficiencies in the TCP/IP protocol?

This investigation primarily looked at throughput rates associated with TCP transfers, not User Datagram Protocol (UDP) transfers. The UDP frames have a header of 8 bytes and the TCP frames have a header of 20 bytes. Also, UDP is not a reliable transport protocol.

How much of a throughput can be achieved using UDP and what problems occur when using an unreliable transfer protocol?

File transfers using the `rcp` system call displayed a throughput rate of only 13.54 Mbps when the transferred data is written to disk. What percentage of this bottleneck is caused by the throughput rate on the SCSI-2 controller and what percentage is caused by other overhead associated with file transfers?

APPENDIX A: NTTCP PROGRAM and TEST SCRIPTS

DOIT.SH Script

```
#!/bin/sh

date > start
date > run1_start_time

ttest.sh 65536 2048
ttest.sh 8192 2048
ttest.sh 65536 4096
ttest.sh 8192 4096

date > run3_finish_time
mkdir run3
mv *.log *.out run3/.
mv *time run3/.

date > run4_start_time

ttest.sh 65536 512
ttest.sh 8192 512
ttest.sh 65536 1024
ttest.sh 8192 1024
ttest.sh 65536 2048
ttest.sh 8192 2048
ttest.sh 65536 4096
ttest.sh 8192 4096

date > run1_finish_time

mkdir run1
mv *.log *.out run1/.
mv *time run1/.

date > run2_start_time

ttest.sh 65536 512
ttest.sh 8192 512
ttest.sh 65536 1024
ttest.sh 8192 1024
ttest.sh 65536 2048
ttest.sh 8192 2048
ttest.sh 65536 4096
ttest.sh 8192 4096

date > run4_finish_time

mkdir run4
mv *.log *.out run4/.
mv *time run4/.

date > run5_start_time

ttest.sh 65536 512
ttest.sh 8192 512
ttest.sh 65536 1024
ttest.sh 8192 1024
ttest.sh 65536 2048
ttest.sh 8192 2048
ttest.sh 65536 4096
ttest.sh 8192 4096

date > run2_finish_time

mkdir run2
mv *.log *.out run2/.
mv *time run2/.

date > run3_start_time

ttest.sh 65536 512
ttest.sh 8192 512
ttest.sh 65536 1024
ttest.sh 8192 1024

date > run5_finish_time

mkdir run5
mv *.log *.out run5/.
mv *time run5/.
```

```

date > run6_start_time

ttest.sh 65536 512
ttest.sh 8192 512
ttest.sh 65536 1024
ttest.sh 8192 1024
ttest.sh 65536 2048
ttest.sh 8192 2048
ttest.sh 65536 4096
ttest.sh 8192 4096

date > run6_finish_time

mkdir run6
mv *.log *.out run6/.
mv *time run6/.

date > finish
sleep 5
grep 'Mb/s' tmp1 | awk '{print
$SIZE*1024,$12}' >> ttest.out
cat tmp1 >> ttest.recv.log
SIZE=`expr $SIZE + 8`
done

rm -f tmp1
mv ttest.out ttest.$DATALEN.$NPKTS.out
mv ttest.tran.log
ttest.$DATALEN.$NPKTS.tran.log
mv ttest.recv.log
ttest.$DATALEN.$NPKTS.recv.log

```

TTEST.SH Script

```

#!/bin/sh
#
# Use nttcp to test network throughput.
# Usage: ttest.sh byte_per_write
#           number_of_writes
#
DATALEN=$1
NPKTS=$2

#White to Gold
RECHOST=131.120.1.2
RSH=/usr/ucb/rsh
NTTCP=nttcp

rm -f ttest.out
rm -f ttest.tran.log
rm -f ttest.recv.log

# from 4KB to 60KB windows in steps of 8KB
SIZE=4
while test $SIZE -lt 61
do
    SRSH SRECHOST SNTTCP -r -w$SIZE
    > tmp1 2>&1 &
    sleep 5
    SNTTCP -t -ISDATALEN -n$NPKTS -w$SIZE
    SRECHOST >> ttest.tran.log 2>&1

```

NTTCP Program

```
/*
 *      N T T C P . C
 *
 * Test TCP connection. Makes a connection on port 2000
 * and transfers zero buffers or data copied from stdin.
 *
 * Usable on 4.2, 4.3, and 4.1a systems by defining one of
 * BSD42 BSD43 (BSD41a)
 *
 * Modified for operation under 4.2BSD, 18 Dec 84
 *      T.C. Slattery, USNA
 * Minor improvements. Mike Muuss and Terry Slattery, 16-Oct-85.
 *
 * Modified on 5 Apr 94 for operation under Solaris 2.3 based on changes
 * for the TTCP.C program provided by Don Merritt of ARL.
 *      CPT Mark Schivley, USA
 */
#ifndef lint
static char RCSid[] = "@(#)$Header: /src/opt/bri/sbin/ttcp/RCS/ttcp.c,v 1.2 1993/11/30 20:15:39
root Exp $ (BRL)";
#endif
#define BSD43
/* #define BSD42 */
/* #define BSD41a */
#include <stdio.h>
#include <ctype.h>
#include <errno.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <netdb.h>
#include <sys/time.h>           /* struct timeval */
#ifdef SYSV
#include <sys/times.h>
#include <sys/param.h>
#else
#include <sys/resource.h>
#endif
#ifdef SYSV
#define bcopy(s,d,l) memcpy(d, s, (size_t) l)
#define bzero(s,l) memset(s, 0, (size_t) l)
#endif
struct sockaddr_in sinme;
struct sockaddr_in sinhim;
struct sockaddr_in sindum;
struct sockaddr_in frominet;
int domain, fromlen;
```

```

int fd;                                /* fd of network socket */
int sendwin = 32 * 1024;
int rcvwin = 32 * 1024;
int optlen = sizeof(int);
int buflen = 1024;                      /* length of buffer */
char *buf;                             /* ptr to dynamic buffer */
int nbuf = 1024;                        /* number of buffers to send in sinkmode */
int udp = 0;                            /* 0 = tcp, !0 = udp */
int options = 0;                        /* socket options */
int one = 1;                            /* for 4.3 BSD style setsockopt() */
short port = 2001;                      /* TCP port number */
char *host;                            /* ptr to name of host */
int trans;                            /* 0=receive, !0=transmit mode */
int sinkmode = 1;                        /* 0=normal I/O, !0=sink/source mode */
int verbose = 0;                         /* set TCP_NODELAY socket option */
int nodelay = 0;                        /* 0=use default 1=set to specified size */
int window = 0;                         /* 0=use default 1=set to specified size */
struct hostent *addr;
extern int errno;
char Usage[] = `

Usage: ttcp -t [-options] host <in\n>
      -l##    length of bufs written to network (default 1024)\n\
      -s      don't source a pattern to network, use stdin\n\
      -n##    number of bufs written to network (-s only, default 1024)\n\
      -p##    port number to send to (default 2000)\n\
      -u      use UDP instead of TCP\n\
Usage: ttcp -r [-options] >out\n>
      -l##    length of network read buf (default 1024)\n\
      -s      sink (discard) all data from network\n\
      -p##    port number to listen at (default 2000)\n\
      -B      Only output full blocks, as specified in -l## (for TAR)\n\
      -u      use UDP instead of TCP\n\
`:
char stats[128];
double t;                                /* transmission time */
long nbytes;                            /* bytes on net */
int b_flag = 0;                           /* use mread() */
void prep_timer();
double read_timer();                      /* user, real time (seconds) */
main(argc,argv)
int argc;
char **argv;
{
    unsigned long addr_tmp;
    if (argc < 2) goto usage;
    argv++; argc--;
    while( argc>0 && argv[0][0] == '-' ) {
        switch (argv[0][1]) {
        case 'B':
            b_flag = 1;

```

```

        break;
case 't':
    trans = 1;
    break;
case 'r':
    trans = 0;
    break;
case 'd':
    options |= SO_DEBUG;
    break;
case 'n':
    nbuf = atoi(&argv[0][2]);
    break;
case 'T':
    buflen = atoi(&argv[0][2]);
    break;
case 'w':
    window=1;
    sendwin = 1024 * atoi(&argv[0][2]);
    rcvwin = 1024 * atoi(&argv[0][2]);
    break;
case 's':
    sinkmode = 1; /* source or sink, really */
    break;
case 'p':
    port = atoi(&argv[0][2]);
    break;
case 'u':
    udp = 1;
    break;
default:
    goto usage;
}
argv++; argc--;
}
if(trans) {
/* xmitr */
if(argc != 1) goto usage;
bzero((char *)&sinhim, sizeof(sinhim));
host = argv[0];
if(atoi(host) > 0 ) {
    /* Numeric */
    sinhim.sin_family = AF_INET;
#endif cray
    addr_tmp = inet_addr(host);
    sinhim.sin_addr = addr_tmp;
#else
    sinhim.sin_addr.s_addr = inet_addr(host);
#endif
} else {
    if ((addr=gethostbyname(host)) == NULL)

```

```

        err("bad hostname");
        sinhim.sin_family = addr->h_addrtype;
        bcopy(addr->h_addr,(char*)&addr_tmp,addr->h_length);
#endif cray
        sinhim.sin_addr = addr_tmp;
#else
        sinhim.sin_addr.s_addr = addr_tmp;
#endif cray
    }
    sinhim.sin_port = htons(port);
    sinme.sin_port = 0; /* free choice */
} else {
/* rcvr */
    sinme.sin_port = htons(port);
}
if ((buf = (char *)malloc(buflen)) == (char *)NULL)
err("malloc");
sprintf(stderr,"tcp%:s: nbuf=%d, buflen=%d, port=%d\n",
trans?"-t":"-r",
nbuf, buflen, port);
if ((fd = socket(AF_INET, udp?SOCK_DGRAM:SOCK_STREAM, 0)) < 0)
err("socket");
mes("socket");
/* Try the getsockopt & setsockopt for Solaris here */
#ifndef SOLARIS
if (bind(fd, &sinme, sizeof(sinme)) < 0)
err("bind");
#else
/*
 * Under Solaris, calling connect() on a stream socket binds the
 * socket to an address. If a bind() is done before the connect(),
 * an error "connect: Address family not supported by protocol family"
 * results. Only call bind() for the cases where you're not going
 * to call connect().
 */
if (udp || (!udp && !trans))
if (bind(fd, (struct sockaddr *)&sinme, sizeof(sinme)) < 0)
err("bind");
#endif /* SOLARIS */
if (!udp) {
    if (trans) {
/* We are the client if transmitting */
    if(options) {
#endif BSD42
        if( setsockopt(fd, SOL_SOCKET, options, 0, 0) < 0)
#endif BSD43
#ifndef SOLARIS
        if( setsockopt(fd, SOL_SOCKET, options, &one, sizeof(one)) < 0)
#endif
        if( setsockopt(fd, SOL_SOCKET, options, (char *) &one, sizeof(one)) <
0)

```

```

#endif /* SOLARIS */
#endif
        err("setsockopt");
    }

#ifndef SOLARIS
    if(connect(fd, &sinhim, sizeof(sinhim)) < 0) {
#else
    if(connect(fd, (struct sockaddr *) &sinhim, sizeof(sinhim)) < 0) {
#endif /* SOLARIS */
        err("connect");
    }
    mes("connect");
    if(window){
        if(setsockopt(fd, SOL_SOCKET, SO_SNDBUF, (char *) &sendwin,
                      sizeof(sendwin)) < 0)
            printf("get send window size didn't work\n");
        if(setsockopt(fd, SOL_SOCKET, SO_RCVBUF, (char *) &rcvwin,
                      sizeof(rcvwin)) < 0)
            printf("get rcv window size didn't work\n");
        if(getsockopt(fd, SOL_SOCKET, SO_RCVBUF, (char *) &sendwin, &optlen) < 0)
            printf("get send window size didn't work\n");
        else printf("send window size = %d\n", sendwin);
        if(getsockopt(fd, SOL_SOCKET, SO_RCVBUF, (char *) &rcvwin, &optlen) < 0)
            printf("get rcv window size didn't work\n");
        else printf("receive window size = %d\n", rcvwin);
    }
} else {
/* otherwise, we are the server and
 * should listen for the connections
 */
#ifndef SOLARIS
    listen(fd,0); /* allow a queue of 0 */
#else
/*
 * Under Solaris, specifying a queue length of 0
 * results in a "connection refused".
 */
    listen(fd,1);
#endif /* SOLARIS */
    if(options) {
#ifndef BSD42
        if(setsockopt(fd, SOL_SOCKET, options, 0, 0) < 0)
#endif BSD43
#ifndef SOLARIS
        if(setsockopt(fd, SOL_SOCKET, options, &one, sizeof(one)) < 0)
#endif
        else
            if(setsockopt(fd, SOL_SOCKET, options, (char *) &one, sizeof(one)) <
0)
#endif /* SOLARIS */
#endif
        err("setsockopt");
    }
}

```

```

}

fromlen = sizeof(frominet);
domain = AF_INET;
#ifndef SOLARIS
    if((fd=accept(fd, &frominet, &fromlen) ) < 0)
#else
    if((fd=accept(fd, (struct sockaddr *) &frominet, &fromlen) ) < 0)
#endif /* SOLARIS */
        err("accept");
    mes("accept");
if (window){
    if (setsockopt (fd, SOL_SOCKET, SO_SNDBUF, (char *) &sendwin,
    sizeof(sendwin)) < 0 )
        printf("get send window size didn't work\n");
    if (setsockopt (fd, SOL_SOCKET, SO_RCVBUF, (char *) &rcvwin,
    sizeof(rcvwin)) < 0 )
        printf("get rcv window size didn't work\n");
    if (getsockopt (fd, SOL_SOCKET, SO_RCVBUF, (char *) &sendwin, &optlen) < 0 )
        printf("get send window size didn't work\n");
    else printf("send window size = %d\n", sendwin);
    if (getsockopt (fd, SOL_SOCKET, SO_RCVBUF, (char *) &rcvwin, &optlen) < 0 )
        printf("get rcv window size didn't work\n");
    else printf("receive window size = %d\n", rcvwin);
}
}
}
prep_timer();
errno = 0;
if (sinkmode) {
register int cnt;
if (trans) {
    pattern( buf, buflen );
    if(udp) (void)Nwrite( fd, buf, 4 ); /* rcvr start */
    while (nbuf-- && Nwrite(fd,buf,buflen) == buflen)
        nbytes += buflen;
    if(udp) (void)Nwrite( fd, buf, 4 ); /* rcvr end */
} else {
    while ((cnt=Nread(fd,buf,buflen)) > 0) {
        static int going = 0;
        if( cnt <= 4 ) {
            if( going )
                break; /* "EOF" */
            going = 1;
            prep_timer();
        } else
            nbytes += cnt;
    }
}
} else {
register int cnt;
if (trans) {

```

```

while((cnt=read(l.buf,buflen)) > 0 &&
      Nwrite(fd,buf,cnt) == cnt)
      nbytes += cnt;
} else {
    while((cnt=Nread(fd,buf,buflen)) > 0 &&
          write(l.buf,cnt) == cnt)
          nbytes += cnt;
}
}
if(errno) err("IO");
(void)read_timer(stats,sizeof(stats));
if(udp&&trans) {
    (void)Nwrite(fd,buf,4); /* rcvr end */
    (void)Nwrite(fd,buf,4); /* rcvr end */
    (void)Nwrite(fd,buf,4); /* rcvr end */
    (void)Nwrite(fd,buf,4); /* rcvr end */
}
fprintf(stdout,
        "ttcp%: %ld bytes in %.2f real seconds = %.2f KB/sec = %.4f Mb/s\n",
        trans?"-t":"-r",
        nbytes, realt, ((double)nbytes)/realt/1024,
        ((double)nbytes)/realt/128000 );
if(verbose) {
    fprintf(stdout,
            "ttcp%: %ld bytes in %.2f CPU seconds = %.2f KB/cpu sec\n",
            trans?"-t":"-r",
            nbytes, cput, ((double)nbytes)/cput/1024 );
}
exit(0);
usage:
    fprintf(stderr,Usage);
    exit(1);
}
err(s)
char *s;
{
    fprintf(stderr,"ttcp%: ", trans?"-t":"-r");
    perror(s);
    fprintf(stderr,"errno=%d\n",errno);
    exit(1);
}
mes(s)
char *s;
{
    fprintf(stderr,"ttcp%: %s\n", trans?"-t":"-r", s);
}
pattern(cp,cnt)
register char *cp;
register int cnt;
{
    register char c;

```

```

c = 0;
while( cnt-- > 0 ) {
    while( !isprint((c&0x7F)) ) c++;
    *cp++ = (c++&0x7F);
}
*******/

#ifdef SYSV
extern long time();
#endif sgi
static void tvsub();
static structtimeval time0; /* Time at which timeing started */
#ifndef
static long time0;
#endif
static struct tms tms0;
#ifndef
static structtimeval time0; /* Time at which timeing started */
static structrusage ru0; /* Resource utilization at the start */
static void prusage();
static void tvadd();
static void tvsub();
static void psecs();
#endif
/* P R E P _ T I M E R
 */
void
prep_timer()
{
#ifdef SYSV
#endif sgi
    gettimeofday(&time0, (struct timezone *)0);
#ifndef
    (void)time(&time0);
#endif
#ifndef
    (void)times(&tms0);
#endif
#ifndef
    gettimeofday(&time0, (struct timezone *)0);
    getrusage(RUSAGE_SELF, &ru0);
#endif
}
/* R E A D _ T I M E R
 */
double
read_timer(str.len)
char *str;
{
#endif SYSV

```

```

long now;
struct tms tmsnow;
char line[132];
#endif sgi
    struct timeval timedol;
    struct timeval td;
    gettimeofday(&timedol, (struct timezone *)0);
    tvsub( &td, &timedol, &time0 );
    realt = td.tv_sec + ((double)td.tv_usec) / 1000000;
#else
    (void)time(&now);
    realt = now-time0;
#endif
(void)times(&tmsnow);
cput = tmsnow.tms_utime - tms0.tms_utime;
cput /= HZ;
if( cput < 0.00001 ) cput = 0.01;
if( realt < 0.00001 ) realt = cput;
sprintf(line,"%g CPU secs in %g elapsed secs (%g%%)", 
        cput, realt,
        cput/realt*100 );
(void)strncpy( str, line, len );
return( cput );
#else
/* BSD */
    struct timeval timedol;
    struct rusage ru1;
    struct timeval td;
    struct timeval tend, tstart;
    char line[132];
    getrusage(RUSAGE_SELF, &ru1);
    gettimeofday(&timedol, (struct timezone *)0);
    prusage(&ru0, &ru1, &timedol, &time0, line);
    (void)strncpy( str, line, len );
/* Get real time */
    tvsub( &td, &timedol, &time0 );
    realt = td.tv_sec + ((double)td.tv_usec) / 1000000;
/* Get CPU time (user+sys) */
    tvadd( &tend, &ru1.ru_utime, &ru1.ru_stime );
    tvadd( &tstart, &ru0.ru_utime, &ru0.ru_stime );
    tvsub( &td, &tend, &tstart );
    cput = td.tv_sec + ((double)td.tv_usec) / 1000000;
    if( cput < 0.00001 ) cput = 0.00001;
    return( cput );
#endif
}
#ifndef SYSV
static void
prusage(r0, r1, e, b, outp)
    register struct rusage *r0, *r1;
    struct timeval *e, *b;

```

```

char *outp;
{
    struct timeval tdiff;
    register time_t t;
    register char *cp;
    register int i;
    int ms;
    t = (r1->ru_utime.tv_sec-r0->ru_utime.tv_sec)*100+
        (r1->ru_utime.tv_usec-r0->ru_utime.tv_usec)/100000+
        (r1->ru_stime.tv_sec-r0->ru_stime.tv_sec)*100+
        (r1->ru_stime.tv_usec-r0->ru_stime.tv_usec)/10000;
    ms = (e->tv_sec-b->tv_sec)*100 + (e->tv_usec-b->tv_usec)/10000;
#define END(x){while(*x) x++;}

    cp = "%Uuser %Ssys %Ereal %P %Xi+%Dd %Mmaxrss %F+%Rpf %Ccsw";
    for (; *cp; cp++) {
        if (*cp != '%')
            *outp++ = *cp;
        else if (cp[1]) switch(*++cp) {
            case 'U':
                tvsub(&tdiff, &r1->ru_utime, &r0->ru_utime);
                sprintf(outp,"%d.%01d", tdiff.tv_sec, tdiff.tv_usec/100000);
                END(outp);
                break;
            case 'S':
                tvsub(&tdiff, &r1->ru_stime, &r0->ru_stime);
                sprintf(outp,"%d.%01d", tdiff.tv_sec, tdiff.tv_usec/100000);
                END(outp);
                break;
            case 'E':
                psecs(ms / 100, outp);
                END(outp);
                break;
            case 'P':
                sprintf(outp,"%d%%", (int) (t*100 / ((ms ? ms : 1))));
                END(outp);
                break;
            case 'W':
                i = r1->ru_nswap - r0->ru_nswap;
                sprintf(outp,"%d", i);
                END(outp);
                break;
            case 'X':
                sprintf(outp,"%d", t == 0 ? 0 : (r1->ru_ixrss-r0->ru_ixrss)/t);
                END(outp);
                break;
            case 'D':
                sprintf(outp,"%d", t == 0 ? 0 :
                    (r1->ru_idrss+r1->ru_isrss-(r0->ru_idrss+r0->ru_isrss))/t);
                END(outp);
                break;
            case 'K':

```

```

        sprintf(outp,"%d", t == 0 ? 0 :
            ((r1->ru_ixrss+r1->ru_isrss+r1->ru_idrss) -
             (r0->ru_ixrss+r0->ru_idrss+r0->ru_isrss))/t);
    END(outp);
    break;
case 'M':
    sprintf(outp,"%d", r1->ru_maxrss/2);
    END(outp);
    break;
case 'F':
    sprintf(outp,"%d", r1->ru_majflt-r0->ru_majflt);
    END(outp);
    break;
case 'R':
    sprintf(outp,"%d", r1->ru_minflt-r0->ru_minflt);
    END(outp);
    break;
case 'T':
    sprintf(outp,"%d", r1->ru_inblock-r0->ru_inblock);
    END(outp);
    break;
case 'O':
    sprintf(outp,"%d", r1->ru_oublock-r0->ru_oublock);
    END(outp);
    break;
case 'C':
    sprintf(outp,"%d+%d", r1->ru_nvcsw-r0->ru_nvcsw,
           r1->ru_nvcsw-r0->ru_nvcsw );
    END(outp);
    break;
}
}
*outp = '\0';
}

static void
tvadd(tsum, t0, t1)
    struct timeval *tsum, *t0, *t1;
{
    tsum->tv_sec = t0->tv_sec + t1->tv_sec;
    tsum->tv_usec = t0->tv_usec + t1->tv_usec;
    if (tsum->tv_usec > 1000000)
        tsum->tv_sec++, tsum->tv_usec -= 1000000;
}

static void
tvsub(tdiff, t1, t0)
    struct timeval *tdiff, *t1, *t0;
{
    tdiff->tv_sec = t1->tv_sec - t0->tv_sec;
    tdiff->tv_usec = t1->tv_usec - t0->tv_usec;
    if (tdiff->tv_usec < 0)
        tdiff->tv_sec--, tdiff->tv_usec += 1000000;
}

```

```

}

static void
psecs(l.cp)
long l;
register char *cp;
{
    register int i;
    i = l / 3600;
    if (i) {
        sprintf(cp, "%d:", i);
        END(cp);
        i = l % 3600;
        sprintf(cp, "%d%d", (i/60) / 10, (i/60) % 10);
        END(cp);
    } else {
        i = l;
        sprintf(cp, "%d", i / 60);
        END(cp);
    }
    i %= 60;
    *cp++ = ':';
    sprintf(cp, "%d%d", i / 10, i % 10);
}

#endif
/*
 *      N R E A D
 */
Nread( fd, buf, count )
{
    struct sockaddr_in from;
    int len = sizeof(from);
    register int cnt;
    if( udp ) {
        cnt = recvfrom( fd, (char *) buf, count, 0, (struct sockaddr *) &from, &len );
    } else {
        if( b_flag )
            cnt = mread( fd, buf, count );/* fill buf */
        else
            cnt = read( fd, buf, count );
    }
    return(cnt);
}
/*
 *      N W R I T E
 */
Nwrite( fd, buf, count )
{
    register int cnt;
    if( udp ) {
again:
    cnt = sendto( fd, (char *) buf, count, 0, (struct sockaddr *) &sinhim,

```

```

sizeof(sinhim) );
    if( cnt<0 && errno == ENOBUFS ) {
        delay(18000);
        errno = 0;
        goto again;
    }
    else {
        cnt = write( fd , . . . count );
    }
    return(cnt);
}
delay(us)
{
    struct timeval tv;
    tv.tv_sec = 0;
    tv.tv_usec = us;
    (void)select( 1, (fd_set *)0, (fd_set *)0, (fd_set *)0, &tv );
    return(1);
}

/*
 *      M R E A D
 *
 * This function performs the function of a read(II) but will
 * call read(II) multiple times in order to get the requested
 * number of characters. This can be necessary because
 * network connections don't deliver data with the same
 * grouping as it is written with. Written by Robert S. Miles, BRL.
 */
int
mread(fd, bufp, n)
int fd;
register char*bufp;
unsigned n;
{
    register unsigned count = 0;
    register int nread;
    do {
        nread = read(fd, bufp, n-count);
        if(nread < 0) {
            perror("tcp_mread");
            return(-1);
        }
        if(nread == 0)
            return((int)count);
        count += (unsigned)nread;
        bufp += nread;
    } while(count < n);
    return((int)count);
}
#endif
static void

```

```
tvsub(tdiff, t1, t0)
    struct timeval *tdiff, *t1, *t0;
{
    tdiff->tv_sec = t1->tv_sec - t0->tv_sec;
    tdiff->tv_usec = t1->tv_usec - t0->tv_usec;
    if (tdiff->tv_usec < 0)
        tdiff->tv_sec--, tdiff->tv_usec += 1000000;
}
#endif
```

APPENDIX B: RCP PROGRAM

```
#include <stdio.h>
#include <sys/time.h>

main ()
{
    long elapsed_sec, /* Seconds variable */
          elapsed_usec; /* Microseconds variable */

    int file_size;

    float total_time,
          part_usec,
          transfer_rate;

    float average_time = 0;

    int loop_counter,
        a,           /* Subroutine result variables */
        b;
    int n = 5;

    char name[30], system_name[30];
    char rcp_string[30] = "rcp";
    char blank_string[2] = " ";
    int true = 1;
    char answer[2];
    char* get_name(char *string);

    /* Variable structure defns */

    struct timeval timestart, timedone;
    struct timezone zonestart, zonedone;

    /* Get file name & Dest machine name & path */

    printf("\n\n\n Here is a list of available files for transferring: \n\n");
    system ("ls -al");

    while(answer[0] != 'y')
    {
        printf("\n Input the file name to be transferred: \n\n");
        gets(name);
        printf("\n Is the below input correct? Enter y if yes or n if incorrect: \n\n");
    }
}
```

```

    puts(name);
    printf("\n");
    gets(answer);
}
answer[0] = 'n'; /* reset for next loop */

/* Get file size */

while(answer[0] != 'y')
{
    printf("\n Input the file size to be transferred: \n\n");
    scanf("%d", &file_size);
    printf("\n Is the below input correct? Enter y if yes or n if incorrect: \n\n");
    printf("%d\n", file_size);
    gets(answer);
    gets(answer);
    answer[0] = 'y';
}

answer[0] = 'n'; /* reset for next loop */

while(answer[0] != 'y')
{
    printf("\n Input the Dest machine name & path to be transferred: \n\n");
    printf("An example would be: gold-fddi:/usr/test/wtog_test\n\n");
    gets(system_name);
    printf("\n Is the below input correct? Enter y if yes or n if incorrect: \n\n");
    puts(system_name);
    printf("\n");
    gets(answer);
}

strcat(rcp_string, blank_string);
strcat(rcp_string, name);
strcat(rcp_string, blank_string);
strcat(rcp_string, system_name);

/* Set up outer loop to execute transfers n times */
for (loop_counter = 1; loop_counter <= n; loop_counter += 1)
{
    /* Get start time in sec&usec and check if successful */
    a = gettimeofday(&timestart, zonestart);
    if (a != 0)
        printf ("Oops ! %d\n", a);
    /* Use system call to do file transfer */
    system (rcp_string);
    /* system ("rcp american_pie.au gold-fddi:/usr/test/wtog_test"); */
    /* Get stop time in sec&usec and check if successful */
    b = gettimeofday(&timedone, zonedone);
}

```

```

if (b != 0)
    printf ("Oops! %d\n", b);
    /* Get structure values for calculations. */
elapsed_sec = timedone.tv_sec - timestart.tv_sec;
elapsed_usec = timedone.tv_usec - timestart.tv_usec;
    /* Make sure that we account for the usec */
    /* variable rolling over (through zero) */
if (elapsed_sec >= 1 )
{
    if (elapsed_usec < 0)
    {
        elapsed_sec -= 1;
        elapsed_usec += 1000000;
    }
}
/* Convert the usec variable to a floating point number. */
part_usec = elapsed_usec/1.0e6;
/* Add the seconds to the microseconds to get a real number */
total_time = elapsed_sec + part_usec;
/* And print the results on the CRT */
printf ("%f\n%f\n", total_time, ((file_size*8/total_time)/1000000));
average_time += total_time;
}

/* Print out the results of the avg transfer rate */

printf("\n\nIs this time correct? %f", average_time);

printf("\nThe average time was %f and the average transfer rate was %f\n",
((file_size*8/total_time)/1000000));

/* This is the end of the control loop. */
exit (0);
}

```

APPENDIX C: NEAL NELSON BENCHMARK RESULTS

TABLE 9: CPU SUBSYSTEM

GOLD2.SOL	White	Gold
CPU Type	Sparc	Sparc
CPU Clock Speed	45 MHz	50 MHz
Total Size of Main Memory	224 Mbytes	224 Mbytes
Speed of Main Memory Chips	80 ns	80 ns
Type and Speed of Math Coprocessor	None	None
Number of Main CPUs	2	2

TABLE 10: DISK SUBSYSTEM

	White	Gold
Total Number of Disk Controllers	1	1
Total Number of Disk Devices	2	2
Disk Drive Type	SCSI	SCSI
Disk Drive Brand/Model	Seagate	Seagate
Disk Average Seek Time Seagate ST11200 Seagate ST1480	1-10.5ms 1-10.5ms	2-10.5 ms
Does system have I/O buses separate from the main bus?	Yes	Yes

TABLE II: CACHE INFORMATION

	White	Gold
Does the system have instruction or data cache?	Yes	Yes
How many levels of instruction/data cache are there?	2	2
How is cache coherency accomplished?	Snooping with invalidation	Snooping with invalidation
Does CPU have separate instruction and data caches?	Yes	Yes
Total size of all instructions/data caches: On-board Instruction Data	20 Kbytes 16 Kbytes	20 Kbytes 16 Kbytes
(Note: External SuperCache controller provides 1 Mbyte external cache)		
Total swap	approx 280 Mbytes	approx 280 Mbytes

Group 1: Tests a mix of activities that are intended to approximate the processing activities for the following five types of users. Group 1 includes the following tests:

- 1) Simulated Office Automation Workload
- 2) Simulated Database Workload
- 3) Simulated Software Development Workload
- 4) Simulated Transaction Processing Workload
- 5) Simulated Calculation Workload (Math/Statistics/CAD/CAM)

Group 2: Tests designed to perform various types of calculation tasks and thereby profile the performance of the computer's calculation subsystem. Group 2 includes the following tests:

- 6) Write to Shared Memory
- 7) Read from Memory, Small Instruction Area, Small Data Area
- 8) Read from Memory, Small Instruction Area, Larger Data Area
- 9) Read from Memory, Larger Instruction Area, Small Data Area
- 10) Read from Memory, Larger Instruction Area, Larger Data Area
- 11) Make Machine Page or Swap with 'malloc' and 'free'
- 12) Combined Integer and Floating Point Math
- 13) Math Library Functions
- 14) Semaphores, Shared Memory, Context Switch
- 15) Write to and Read from Pipes, Context Switch
- 16) Sample System Calls
- 17) Increasing Depth of Function Calls

Group 3: Tests that perform a series of disk input and output functions to profile the performance of the disk subsystem. Group 3 includes the following tests:

- 18) 1024 byte Sequential Reads from Unix File(s)
- 19) 1024 byte Sequential Writes from Unix File(s)
- 20) 8192 byte Sequential Reads from Unix File(s)
- 21) 3192 byte Sequential Writes to Unix File(s)
- 22) 4096 byte Synchronized Reads from Unix File(s)
- 23) 4096 byte Synchronized Reads from Raw Device(s)
- 24) 16384 byte Synchronized Reads from Unix File(s)
- 25) 16384 byte Synchronized Reads from Raw Device(s)
- 26) 4096 byte Pseudo Random Reads from Unix File(s)
- 27) 4096 byte Pseudo Random Reads from Raw Device(s)
- 28) Profile Disk Cache for Unix File(s)
- 29) Profile Disk Cache for Raw Device(s)
- 30) 8192 byte Sequential Writes then 'sync'

Gold Verses White, Two Processors

TABLE 12: GOLD2.SOL VRS WHITE2.SOL, TEST 1 & 2 & 3 & 4

Load	Test 1		Test 2		Test 3		Test 4	
	White Secs	Gold Secs	White Secs	Gold Secs	White Secs	Gold Secs	White Secs	Gold Secs
1	202	163	117	97	116	98	12	107
2	284	166	120	101	117	99	118	99
3	268	217	166	141	16	139	157	138
4	343	293	211	185	202	176	191	167
5	339	333	300	243	245	260	227	199
6	401	339	318	311	30	241	273	225
7	488	389	396	324	31	289	321	261
8	566	458	48	399	318	326	369	300
9	653	528	572	466	364	305	369	337
10	738	590	657	560	392	344	353	319
11	88	659	76	687	460	386	393	351
12	932	756	958	763	584	429	434	402
13	1012	841	1185	896	560	472	502	421
14	1132	928	1322	1023	686	516	542	568
15	1192	74	171	1286	647	556	588	486
16	1278	168	180	1597	728	598	619	519
17	1378	1125	2004	1534	769	655	675	563
18	1540	1261	219	1789	822	666	694	599
19	1647	1351	2413	1920	982	727	805	655
20	1669	1404	2256	2112	92	750	800	650

TABLE 13: GOLD2.SOL VRS WHITE2.SOL, TEST 5 & 6 & 7 & 8

Load	Test 5		Test 6		Test 7		Test 8	
	White Secs	Gold Secs	White Secs	Gold Secs	White Secs	Gold Secs	White Secs	Gold Secs
1	263	164	128	103	130	106	130	105
2	286	167	128	104	131	106	133	107
3	273	221	192	135	195	160	205	166
4	333	298	254	204	257	211	281	243
5	367	319	318	266	322	259	399	335
6	477	398	378	307	391	311	514	436
7	585	477	432	353	447	343	641	539
8	781	576	487	406	507	408	765	641
9	798	641	540	443	551	452	846	722
10	931	737	612	493	611	560	934	831
11	999	818	676	547	678	554	1095	921
12	1157	926	739	611	748	620	1257	1069
13	1290	1051	861	664	869	680	1359	1196
14	1377	1124	866	712	883	725	1522	1303
15	1707	1376	914	757	948	769	1905	1620
16	1953	1573	983	811	1085	815	2216	1844
17	2082	1693	1043	853	1067	881	2377	1996
18	2239	1786	1116	901	1124	926	2530	2147
19	2385	1912	1171	972	1198	982	2738	2279
20	2497	2025	1226	1024	1246	1046	2870	2458

TABLE 14: GOLD2.SOL VRS WHITE2.SOL, TEST 9 & 10 & 11 & 12

Load	Test 9		Test 10		Test 11		Test 12	
	White Secs	Gold Secs						
1	130	106	130	106	—	—	109	87
2	131	107	133	108	—	—	108	87
3	283	162	269	169	—	—	162	131
4	268	219	294	249	—	—	216	181
5	339	284	426	366	—	—	274	219
6	469	343	533	463	—	—	325	263
7	488	487	699	583	—	—	378	368
8	560	468	833	766	—	—	434	351
9	644	537	967	793	—	—	485	391
10	725	669	1186	936	—	—	540	436
11	887	697	1223	1044	—	—	596	488
12	887	773	1391	1260	—	—	649	523
13	986	834	1544	1318	—	—	718	569
14	1862	985	1726	1448	—	—	761	615
15	1141	983	2168	1847	—	—	810	653
16	1244	1052	2355	2023	—	—	866	764
17	1296	1136	2588	2139	—	—	921	745
18	1378	1196	2748	2330	—	—	986	787
19	1462	1278	2956	2472	—	—	1046	855
20	1543	1342	3067	2760	—	—	1105	885

TABLE 15: GOLD2.SOL VRS WHITE2.SOL, TEST 13 & 14 & 15 & 16

Load	Test 13		Test 14		Test 15		Test 16	
	White Secs	Gold Secs						
1	102	81	38	28	109	97	52	46
2	103	81	141	124	131	111	56	56
3	158	126	217	187	179	156	85	74
4	211	175	290	253	245	217	118	98
5	262	223	393	334	368	269	145	121
6	344	248	491	421	386	328	175	147
7	377	301	588	501	434	395	265	172
8	422	341	764	593	516	452	239	196
9	485	396	813	678	576	501	267	219
10	525	430	986	774	626	548	303	244
11	593	469	1013	848	686	611	329	280
12	685	535	1185	951	750	673	359	300
13	713	586	1265	1039	816	699	403	317
14	779	618	1296	1098	874	752	418	356
15	868	648	1410	1173	965	791	443	381
16	981	775	1541	1257	1048	839	471	383
17	897	747	1596	1384	1057	982	496	417
18	1068	826	1765	1416	1127	932	520	447
19	1061	863	1810	1513	1176	969	555	481
20	1118	932	1941	1662	1238	1118	612	490

TABLE 16: GOLD2.SOL VRS WHITE2.SOL, TEST 17 & 18 & 19 & 20

Load	Test 17		Test 18		Test 19		Test 20	
	White Secs	Gold Secs						
1	161	82	5	5	18	19	2	2
2	95	76	6	5	92	93	2	2
3	144	117	9	7	137	145	3	2
4	260	169	12	10	231	221	4	3
5	270	217	15	13	325	372	5	4
6	340	274	23	19	388	378	10	8
7	579	468	27	24	433	427	14	12
8	839	685	32	27	518	474	17	14
9	1877	849	37	30	540	539	19	17
10	1356	1083	39	34	655	574	21	18
11	1631	1314	43	38	691	662	24	20
12	1887	1533	49	42	694	727	28	22
13	2188	1761	332	334	1662	1230	300	320
14	2478	2085	298	273	1898	2316	229	426
15	2734	2213	254	442	2393	2149	264	252
16	3872	2631	266	268	1683	1714	257	246
17	3347	2767	274	278	1920	1865	268	270
18	3679	2939	288	295	2696	2646	282	284
19	3998	3364	309	299	3003	2247	300	299
20	4337	3574	324	324	2238	2139	326	331

TABLE 17: GOLD VRS WHITE2.SOL, TEST 21 & 22 & 23 & 24

Load	Test 21		Test 22		Test 23		Test 24	
	White Secs	Gold Secs						
1	16	16	5	2	4	3	2	1
2	115	114	3	2	4	3	2	2
3	154	166	4	3	6	5	3	2
4	217	224	6	5	8	7	4	3
5	313	292	7	6	11	10	5	4
6	347	286	14	12	14	12	9	7
7	472	356	19	16	18	15	13	11
8	691	412	23	19	21	18	16	13
9	556	499	28	22	24	26	18	15
10	688	499	28	25	243	366	20	16
11	571	648	33	28	223	230	37	36
12	613	733	38	32	177	174	51	48
13	756	655	277	233	193	188	218	193
14	835	938	333	367	542	259	178	238
15	788	887	385	543	266	261	181	197
16	907	820	527	567	266	196	193	485
17	885	919	407	424	538	215	266	449
18	934	1037	483	478	241	236	500	376
19	951	1091	135	468	240	251	338	351
20	1171	1175	927	930	277	213	348	481

TABLE 18: GOLD2.SOL VRS WHITE2.SOL, TEST 25 & 26 & 27 & 28

Load	Test 25		Test 26		Test 27		Test 28	
	White Secs	Gold Secs	White Secs	Gold Secs	White Secs	Gold Secs	White Secs	Gold Secs
1	3	2	3	2	3	2	3	1
2	4	3	3	2	4	3	2	1
3	6	5	4	3	6	5	2	2
4	8	6	5	4	7	6	3	3
5	9	8	7	6	10	9	4	3
6	13	11	11	9	13	11	5	4
7	15	13	17	14	17	15	8	5
8	18	15	22	18	20	17	7	6
9	20	17	26	22	23	20	15	7
10	366	345	36	25	264	366	10	9
11	466	394	47	41	719	662	9	8
12	491	495	68	52	942	930	11	10
13	601	507	412	426	935	930	5	4
14	549	498	358	624	1163	1166	11	10
15	585	525	348	847	1251	1195	16	10
16	769	563	1128	1169	1354	1279	31	21
17	644	635	1259	1274	1549	1498	31	31
18	751	765	1576	1567	1688	1588	79	59
19	951	943	1701	1645	1788	1895	82	68
20	937	1006	1925	1897	1913	1916	116	106

TABLE 19: GOLD2.SOL VRS WHITE2.SOL, TEST 29 & 30

Load	Test 29		Test 30	
	White Secs	Gold Secs	White Secs	Gold Secs
1	1	1	169	1465
2	1	1	146	1382
3	1	1	154	1386
4	2	1	162	1511
5	2	2	1552	1583
6	3	3	1766	1713
7	4	3	2626	1745
8	4	5	2469	2669
9	4	4	2913	2498
10	2	4	2522	2766
11	38	39	3317	2781
12	62	59	274	2226
13	78	71	276	2249
14	89	97	2783	2268
15	160	161	2621	2533
16	166	167	2682	2733
17	126	131	2576	2694
18	139	125	3664	2661
19	142	133	3666	2666
20	146	156	2862	2786

Gold One Processor Verses Gold Two Processors Results

TABLE 20: GOLD1.SOL VRS GOLD2.SOL, TEST 1 & 2 & 3 & 4

Load	Test 1		Test 2		Test 3		Test 4	
	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold Secs	Gold1 Secs	Gold2 Secs
1	168	163	199	177	199	196	166	167
2	285	166	176	181	176	199	163	99
3	336	217	231	141	223	139	216	138
4	446	293	346	185	346	176	296	167
5	538	333	367	243	347	266	322	199
6	649	339	514	311	396	241	346	225
7	768	349	633	324	441	289	382	261
8	943	438	826	399	533	326	436	366
9	1050	528	917	468	686	385	493	337
10	1158	599	1095	560	680	344	549	319
11	1346	639	1266	687	767	386	639	351
12	1549	756	1472	763	983	429	735	482
13	1638	841	1636	896	981	472	773	421
14	1818	928	1838	1023	1043	516	824	568
15	1958	984	2379	1286	1153	536	911	496
16	2098	1043	2426	1557	1221	598	943	519
17	2236	1125	2435	1534	1296	655	1025	543
18	2383	1261	3201	1769	1346	666	1095	599
19	2512	1351	3368	1956	1484	727	1126	635
20	2672	1484	3466	2112	1553	756	1215	650

TABLE 21: GOLD1.SOL VRS GOLD2.SOL, TEST 5 & 6 & 7 & 8

Load	Test 5		Test 6		Test 7		Test 8	
	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold Secs	Gold1 Secs	Gold2 Secs
1	168	166	167	165	166	166	167	165
2	284	167	289	184	226	166	214	167
3	333	221	367	155	312	166	321	166
4	444	298	399	284	469	211	445	243
5	593	319	494	246	529	259	636	235
6	785	398	573	367	601	311	667	436
7	922	477	689	333	684	343	942	339
8	1155	576	753	466	769	468	1171	641
9	1251	641	851	443	868	452	1286	723
10	1456	737	941	493	945	506	1510	831
11	1675	816	1033	547	1082	554	1700	921
12	1867	926	1136	611	1136	626	1864	1051
13	2112	1051	1268	664	1321	686	2082	1190
14	2343	1124	1387	712	1333	725	2271	1383
15	2592	1376	1488	757	1456	769	2559	1620
16	3226	1573	1569	811	1539	815	3221	1844
17	3444	1693	1664	853	1679	881	3343	1936
18	3691	1786	1725	901	1744	926	3485	2147
19	3978	1912	1811	972	1832	983	3668	2279
20	4223	2025	1921	1024	1942	1046	3925	2481

TABLE 22: GOLD1.SOL VRS GOLD2.SOL, TEST 9 & 10 & 11 & 12

Load	Test 9		Test 10		Test 11		Test 12	
	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold Secs	Gold1 Secs	Gold2 Secs
1	112	106	107	106	0	0	86	87
2	219	107	221	106	0	0	177	87
3	323	162	337	160	0	0	243	131
4	435	219	461	249	0	0	353	181
5	545	284	679	348	0	0	445	219
6	663	343	881	463	0	0	523	243
7	783	467	1086	583	0	0	614	386
8	904	468	1286	786	0	0	689	351
9	1052	537	1459	793	0	0	801	391
10	1191	609	1725	939	0	0	894	436
11	1314	697	1922	1044	0	0	970	483
12	1392	773	2157	1286	0	0	1041	523
13	1583	834	2302	1318	0	0	1128	569
14	1643	965	2544	1466	0	0	1286	615
15	1756	983	2584	1847	0	0	1298	633
16	1848	1052	3267	2623	0	0	1484	704
17	1986	1130	3547	2159	0	0	1584	743
18	2088	1190	3797	2390	0	0	1623	787
19	2241	1278	4659	2472	0	0	1683	835
20	2338	1342	4312	2760	0	0	1767	885

TABLE 23: GOLD1.SOL VRS GOLD2.SOL, TEST 13 & 14 & 15 & 16

Load	Test 13		Test 14		Test 15		Test 16	
	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold Secs	Gold1 Secs	Gold2 Secs
1	85	81	28	25	85	97	85	85
2	212	81	101	124	172	111	92	50
3	298	126	167	187	243	156	137	74
4	465	175	277	253	344	217	181	98
5	483	223	357	334	442	249	230	121
6	589	288	447	421	531	328	272	147
7	643	361	523	501	609	395	319	172
8	717	341	608	593	763	452	362	196
9	856	390	710	678	776	501	416	219
10	932	436	762	774	869	548	466	244
11	1086	465	883	868	1016	611	510	280
12	1169	535	935	931	1072	673	549	386
13	1189	586	1056	1069	1135	699	598	317
14	1289	618	1128	1098	1267	752	642	356
15	1340	640	1227	1173	1283	791	703	381
16	1453	775	1376	1257	1384	839	799	383
17	1516	747	1408	1384	1438	982	814	417
18	1666	826	1469	1416	1564	932	850	447
19	1736	843	1581	1513	1649	949	914	481
20	1886	932	1639	1542	1739	1118	935	496

TABLE 24: GOLD1.SOL VRS GOLD2.SOL, TEST 17 & 18 & 19 & 20

Load	Test 17		Test 18		Test 19		Test 20	
	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold Secs	Gold1 Secs	Gold2 Secs
1	83	82	6	6	16	19	1	2
2	155	76	7	5	37	93	3	2
3	237	117	11	7	54	145	4	2
4	327	168	15	10	68	221	6	3
5	413	217	19	13	86	372	8	4
6	500	274	28	19	103	378	14	8
7	581	448	34	24	119	427	17	12
8	1345	685	37	27	135	474	19	14
9	1776	849	43	30	150	539	22	17
10	2386	1043	48	34	165	574	25	18
11	2814	1314	53	38	180	642	27	20
12	3424	1533	60	42	204	727	29	22
13	3561	1761	153	134	428	1230	47	320
14	3961	2085	198	273	437	2316	186	426
15	4389	2213	237	442	438	2149	148	252
16	5482	2431	245	260	476	1714	208	246
17	5465	2767	248	278	528	1845	238	270
18	6327	2939	286	295	544	2846	286	284
19	6379	3364	301	299	587	2247	291	299
20	6442	3574	321	324	674	2139	307	331

TABLE 25: GOLD1.SOL VRS GOLD2.SOL, TEST 21 & 22 & 23 & 24

Load	Test 21		Test 22		Test 23		Test 24	
	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold2 Secs	Gold1 Secs	Gold Secs	Gold1 Secs	Gold2 Secs
1	18	18	2	2	3	3	1	1
2	36	114	4	2	5	3	3	2
3	53	166	6	3	8	5	4	2
4	71	224	8	5	10	7	6	3
5	88	292	10	6	14	9	7	4
6	107	246	17	12	18	12	14	7
7	126	334	23	16	22	15	16	11
8	143	412	25	19	24	18	19	13
9	158	499	31	23	35	20	23	15
10	171	499	33	25	228	366	25	16
11	196	648	39	28	466	236	36	34
12	216	733	39	32	192	174	36	25
13	225	655	167	233	265	150	153	153
14	247	938	328	367	219	259	184	238
15	248	987	412	543	262	261	196	197
16	346	828	524	567	223	196	266	415
17	346	919	677	624	226	215	313	449
18	321	1037	646	476	262	236	279	376
19	344	1091	779	433	288	251	494	351
20	359	1175	1099	985	326	283	436	481

TABLE 26: GOLD1.SOL VRS GOLD2.SOL, TEST 25 & 26 & 27 & 28

Load	Test 25		Test 26		Test 27		Test 28	
	GOLD1 Secs	GOLD2 Secs	GOLD1 Secs	GOLD2 Secs	GOLD1 Secs	GOLD2 Secs	GOLD1 Secs	GOLD2 Secs
1	2	2	2	2	2	2	1	1
2	4	3	4	2	4	3	2	1
3	7	5	6	3	7	5	3	2
4	9	6	8	4	10	6	4	3
5	12	8	10	6	13	9	6	3
6	15	11	15	9	16	11	6	4
7	17	13	21	14	21	15	7	5
8	20	15	26	18	24	17	9	6
9	24	17	32	22	29	20	11	7
10	345	345	37	25	281	306	11	9
11	467	396	43	41	816	842	13	8
12	469	495	47	52	915	936	17	10
13	476	507	364	426	944	950	7	4
14	502	498	611	644	1185	1166	11	10
15	632	525	837	847	1201	1195	14	10
16	764	535	1035	1169	1315	1279	22	21
17	725	635	1313	1274	1469	1488	31	31
18	827	765	1485	1567	1680	1588	63	59
19	969	983	1678	1685	1783	1895	96	98
20	1012	1006	1798	1897	1939	1916	100	106

TABLE 27: GOLD1.SOL VRS GOLD2.SOL, TEST 29 & 30

Load	Test 29		Test 30	
	GOLD1 Secs	GOLD2 Secs	GOLD1 Secs	GOLD2 Secs
1	1	1	979	1405
2	1	1	945	1362
3	2	1	1088	1306
4	3	1	1114	1311
5	3	2	1197	1383
6	4	3	1296	1713
7	5	3	1564	1745
8	5	5	1688	2049
9	7	4	2687	2486
10	3	4	2321	2766
11	62	39	2419	2781
12	62	59	2190	2226
13	75	71	2229	2349
14	86	97	2304	2368
15	94	101	2525	2533
16	116	107	2693	2733
17	127	131	2657	2694
18	131	125	2674	2661
19	142	133	2668	2666
20	152	156	2746	2736

Solaris 2.3 One Processor Versus SunOS 4.1.3 One Processor Results

TABLE 28: GOLD1.SOL VRS GOLD1.SUN, TEST 1 & 2 & 3 & 4

Load	Test 1		Test 2		Test 3		Test 4	
	Gold Secs							
1	105	104	99	97	99	96	106	107
2	205	204	176	180	176	177	163	164
3	334	333	231	246	223	239	216	215
4	446	446	348	358	346	325	290	293
5	538	564	367	388	347	366	322	367
6	689	684	514	517	506	582	340	332
7	768	817	633	661	441	458	382	398
8	963	947	826	817	533	536	486	447
9	1050	1057	917	946	686	618	493	512
10	1158	1224	1095	1120	686	762	549	576
11	1344	1344	1280	1241	767	795	629	629
12	1549	1537	1472	1416	963	975	735	724
13	1688	1672	1656	1517	987	946	773	778
14	1818	1816	1859	1766	1063	1040	824	826
15	1958	1944	2379	2319	1153	1077	911	884
16	2088	2085	2426	2379	1221	1187	943	967
17	2250	2210	2835	2997	1286	1243	1025	1030
18	2343	2315	3201	3248	1350	1306	1095	1095
19	2512	2460	3383	3156	1484	1421	1126	1176
20	2672	2584	3208	3445	1533	1475	1215	1217

TABLE 29: GOLD1.SOL VRS GOLD1.SUN, TEST 5 & 6 & 7 & 8

Load	Test 5		Test 6		Test 7		Test 8	
	Gold Secs							
1	105	104	107	106	106	105	107	106
2	204	207	209	201	206	204	214	207
3	333	324	307	295	312	306	321	307
4	444	459	395	388	405	394	425	436
5	593	616	494	479	529	483	636	666
6	785	782	573	548	681	574	687	785
7	922	909	689	645	684	635	962	973
8	1135	1144	753	735	769	740	1171	1149
9	1251	1286	851	822	888	845	1286	1239
10	1456	1531	941	943	945	918	1516	1453
11	1675	1703	1083	985	1082	1033	1706	1637
12	1847	1861	1136	1084	1136	1100	1864	1773
13	2112	2072	1288	1157	1321	1183	2082	1981
14	2343	2281	1367	1247	1383	1272	2271	2343
15	2602	2582	1405	1376	1486	1403	2637	3037
16	3226	3179	1589	1431	1539	1469	3221	3160
17	3464	3371	1644	1531	1679	1583	3343	3382
18	3691	3614	1725	1635	1744	1639	3483	3501
19	3778	3623	1811	1719	1832	1766	3623	3752
20	4223	4182	1921	1789	1942	1823	3983	4053

TABLE 30: GOLD1.SOL VRS GOLD1.SUN, TEST 9 & 10 & 11 & 12

Load	Test 9		Test 10		Test 11		Test 12	
	Gold Secs							
1	112	106	107	106	0	0	88	87
2	219	219	221	224	0	0	177	174
3	323	326	337	337	0	0	265	30
4	435	435	481	444	0	0	353	346
5	545	548	679	678	0	0	445	431
6	663	654	881	855	0	0	523	517
7	783	767	1064	1070	0	0	614	601
8	904	884	1284	1267	0	0	689	686
9	1052	968	1459	1464	0	0	801	772
10	1191	1118	1725	1630	0	0	894	854
11	1314	1271	1922	1835	0	0	970	937
12	1392	1378	2157	2036	0	0	1041	1025
13	1503	1466	2362	2241	0	0	1123	1108
14	1643	1593	2544	2511	0	0	1266	1201
15	1756	1768	2854	3172	0	0	1298	1291
16	1848	1840	3267	3197	0	0	1484	1391
17	1966	1943	3547	3453	0	0	1584	1469
18	2088	2052	3797	3637	0	0	1623	1550
19	2241	2213	4059	3933	0	0	1683	1623
20	2338	2359	4312	4064	0	0	1767	1731

TABLE 31: GOLD1.SOL VRS GOLD1.SUN, TEST 13 & 14 & 15 & 16

Load	Test 13		Test 14		Test 15		Test 16	
	Gold Secs							
1	85	62	28	68	85	58	85	41
2	212	123	10	145	172	135	92	82
3	298	186	167	273	263	234	137	121
4	405	249	277	368	344	366	181	162
5	483	312	357	464	442	394	236	205
6	589	374	447	567	531	566	272	244
7	643	438	523	674	609	596	319	286
8	717	592	648	774	703	691	362	328
9	836	564	716	913	776	776	416	376
10	932	636	782	997	859	858	466	414
11	1066	749	888	1066	1016	995	510	454
12	1169	801	935	1237	1072	1043	549	497
13	1189	849	1036	1395	1133	1216	598	532
14	1249	956	1128	1429	1287	1260	662	597
15	1340	1040	1227	1585	1283	1406	703	639
16	1453	1101	1376	1723	1364	1415	799	667
17	1516	1129	1488	1895	1436	1506	814	718
18	1640	1230	1489	2010	1564	1612	850	765
19	1734	1283	1581	2088	1659	1719	914	816
20	1866	1399	1659	2132	1739	1815	935	838

TABLE 32: GOLD1.SOL VRS GOLD1.SUN, TEST 17 & 18 & 19 & 20

Load	Test 17		Test 18		Test 19		Test 20	
	Gold Secs							
1	63	76	4	4	16	14	1	2
2	135	149	7	8	37	39	3	5
3	237	224	11	11	54	44	4	7
4	327	311	15	15	69	59	6	10
5	433	409	19	19	86	73	8	12
6	550	525	23	23	103	89	14	15
7	941	1234	34	27	119	107	17	18
8	1345	1945	37	31	135	124	19	21
9	1776	2462	43	35	150	144	22	24
10	2386	3433	48	52	169	163	25	27
11	2814	4134	53	71	190	193	27	34
12	3024	4892	68	344	264	491	29	169
13	3561	5456	133	395	328	911	47	649
14	3961	6441	198	480	437	1064	186	769
15	4359	7058	237	656	438	1115	148	789
16	5082	7875	248	656	470	949	268	618
17	5465	8478	248	646	528	1283	238	1013
18	6327	9400	280	555	544	1530	280	1125
19	6379	10157	301	646	587	1835	291	1226
20	6842	11052	321	834	674	1895	307	1238

TABLE 33: GOLD1.SOL VRS GOLD1.SUN, TEST 21 & 22 & 23 & 24

Load	Test 21		Test 22		Test 23		Test 24	
	Gold Secs							
1	10	10	2	3	3	3	1	2
2	36	32	4	5	5	5	3	4
3	53	46	6	8	8	8	4	6
4	71	61	8	11	10	11	6	9
5	86	77	10	16	14	14	7	11
6	107	92	17	19	18	17	14	14
7	120	111	23	24	22	20	16	16
8	143	127	25	29	24	22	19	19
9	158	147	31	35	29	26	22	21
10	171	168	33	38	229	36	25	24
11	190	190	39	43	400	73	36	247
12	210	208	39	244	192	169	36	367
13	225	230	167	169	265	116	195	297
14	247	249	328	348	219	125	186	398
15	260	276	412	245	262	136	196	399
16	305	292	524	536	223	142	200	440
17	306	318	677	321	224	152	315	411
18	321	345	646	832	242	157	279	476
19	346	343	779	621	288	169	494	542
20	359	393	1099	1015	320	180	436	649

TABLE 34: GOLD1.SOL VRS GOLD1.SUN, TEST 25 & 26 & 27 & 28

Load	Test 25		Test 26		Test 27		Test 28	
	Gold Secs							
1	2	2	2	3	2	2	1	1
2	4	4	4	4	4	4	2	1
3	7	5	6	7	7	7	3	3
4	9	8	8	11	10	10	4	3
5	12	10	10	17	13	14	6	4
6	15	12	15	21	16	17	6	5
7	17	14	21	26	21	19	7	6
8	20	16	26	30	24	23	9	7
9	24	18	32	35	29	26	11	8
10	305	21	37	40	281	29	11	10
11	467	22	43	705	816	32	13	43
12	449	237	47	1174	915	39	17	131
13	476	285	364	1336	984	74	7	193
14	502	224	611	1687	1105	19	11	221
15	652	130	837	1137	1201	36	14	259
16	764	152	1035	1934	1315	1122	22	277
17	725	225	1313	1964	1469	517	31	296
18	827	193	1455	2086	1680	1448	43	319
19	969	148	1678	2361	1783	2248	56	349
20	1012	184	1718	2449	1959	2453	100	389

TABLE 35: GOLD1.SOL VRS GOLD1.SUN, TEST 29 & 30

Load	Test 29		Test 30	
	Gold Secs	Gold Secs	Gold Secs	Gold Secs
1	1	1	979	769
2	1	2	945	474
3	2	3	1088	625
4	3	4	1114	736
5	3	5	1197	785
6	4	8	1296	858
7	5	8	1564	1007
8	5	11	1688	1196
9	7	33	2067	1357
10	3	38	2321	1368
11	42	11	2419	1367
12	62	7	2190	1361
13	75	10	2229	1268
14	84	5	2284	1311
15	94	10	2525	1344
16	110	6	2693	1331
17	127	102	2457	1302
18	131	112	2674	1464
19	142	195	2668	1468
20	152	202	2746	1559

APPENDIX D: NTTCP SINGLE PROCESSOR RESULTS

TABLE 36: SINGLE PARAMETER TEST RESULTS

Test Number	FFrom:	To:	NFS - asynch threads	ITR1	SDT BUM- IIC rx
1st Test	White	Gold	8	8ms	48K
2nd Test	Gold	White	8	8ms	48K
3rd Test & 4th Test	White	Gold	8	8ms	48K
	Gold	White			
5th Test	White	Gold	16	8ms	48K
6th Test	Gold	White	16	8ms	48K
7th Test & 8th Test	White	Gold	16	8ms	48K
	Gold	White			
9th Test	White	Gold	8	5ms	48K
10th Test	Gold	White	8	5ms	48K
11th Test	White	Gold	8	5ms	48K
12th Test	Gold	White			
13th Test	White	Gold	16	5ms	48K
14th Test	Gold	White	16	5ms	48K
15th Test	White	Gold	16	5ms	48K
16th Test	Gold	White			
17th Test	White	Gold	8	11ms	48K
18th Test	Gold	White	8	11ms	48K
19th Test & 20th Test	White	Gold	8	11ms	48K
	Gold	White			
21st Test	White	Gold	16	11ms	48K
22nd Test	Gold	White	16	11ms	48K
23rd Test & 24th Test	White	Gold	16	11ms	48K
	Gold	White			
25th Test	White	Gold	8	25ms	48K
26th Test	Gold	White	8	25ms	48K
27th Test & 28th Test	White	Gold	8	25ms	48K
	Gold	White			
29th Test	White	Gold	16	25ms	48K
30th Test	Gold	White	16	25ms	48K
31st Test & 32nd Test	White	Gold	16	25ms	48K
	Gold	White			
33rd Test	White	Gold	8	8	48K
FDDI Boards switched					
34th Test	Gold	White	8	8	48K
FDDI Boards switched					

TABLE 37: SINGLE PROCESSOR, 1ST TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	40.05	36.06	32.46	31.92	31.51	31.96
12	118.33	29.13	32.77	30.95	24.63	25.42	24.93	26.21
20	32.77	43.69	41.87	40.57	40.57	40.33	40.62	39.86
28	32.77	49.15	38.23	42.65	40.57	40.89	41.67	41.81
36	32.77	43.69	38.23	43.69	41.61	40.89	41.67	42.38
44	32.77	49.15	38.23	42.65	40.57	39.43	42.26	42.09
52	76.96	49.15	38.23	41.61	38.75	37.93	39.35	36.15
60	32.77	43.69	38.23	41.61	33.72	34.37	30.09	30.60

From: White
To: GoldThreads: 8
TTRT: 8msLLC Buffers: 48K
Single Test**TABLE 38: SINGLE PROCESSOR, 2ND TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	34.33	30.34	29.47	30.12	29.98
12	30.04	29.13	29.49	30.34	23.08	21.41	21.16	24.09
20	32.77	30.95	38.23	33.55	33.55	34.59	33.33	34.57
28	32.77	43.69	34.59	36.67	35.89	35.84	35.56	35.85
36	32.77	38.23	36.41	36.67	34.02	34.64	35.37	35.25
44	32.77	49.15	36.41	37.45	35.11	35.00	34.80	35.37
52	163.84	32.77	40.05	35.28	14.42	14.58	13.45	14.21
60	32.77	43.69	32.77	36.67	7.70	7.04	7.56	6.93

From: Gold
To: WhiteThreads: 8
TTRT: 8msLLC Buffers: 48K
Single Test**TABLE 39: SINGLE PROCESSOR, 3RD TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	25.49	29.34	26.55	19.58	20.98	18.93	20.79
12	27.31	26.40	23.35	25.73	18.06	20.37	17.58	19.44
20	24.58	27.31	26.99	29.61	28.29	28.94	28.43	27.37
28	102.60	33.68	26.42	25.57	24.81	28.75	29.03	29.47
36	30.04	32.77	28.61	28.09	29.65	29.49	29.92	27.91
44	30.04	41.87	28.76	30.41	25.92	30.08	30.08	29.29
52	30.04	34.59	32.25	30.97	24.08	25.94	28.24	25.58
60	32.77	28.22	31.68	30.03	26.60	26.37	24.03	25.23

From: White
To: GoldThreads: 8
TTRT: 8msLLC Buffers: 48K
Dual Test

TABLE 40: SINGLE PROCESSOR, 4TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	67.36	27.31	30.58	28.36	20.59	20.35	19.34	20.68
12	27.31	29.13	25.67	25.75	19.40	18.77	18.81	18.98
20	24.58	30.95	26.94	27.87	27.53	26.52	25.26	24.40
28	32.77	29.13	28.76	27.81	25.92	26.26	27.00	25.97
36	32.77	34.59	30.58	28.78	28.47	27.76	26.69	26.1
44	30.04	38.23	31.68	31.38	27.32	27.69	28.15	28.74
52	27.31	23.67	32.40	30.99	14.86	15.30	14.03	14.75
60	27.31	32.77	26.42	32.51	8.58	8.44	7.95	41.07

From: Gold
To: WhiteThreads: 8
TTRT: 8msLLC Buffers: 48K
Dual Test**TABLE 41: SINGLE PROCESSOR, 5TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	38.23	36.67	33.55	32.49	32.44	32.95
12	30.04	32.77	34.59	34.40	26.51	26.17	27.10	27.53
20	32.77	43.69	38.23	40.57	39.53	39.85	40.14	41.26
28	128.04	43.69	41.87	40.57	41.61	42.01	42.28	41.95
36	32.77	38.23	41.87	41.61	41.61	42.09	42.53	41.69
44	136.33	38.23	43.69	42.65	40.57	42.57	42.53	41.98
52	32.77	43.69	38.23	42.65	38.49	38.11	39.00	35.48
60	32.77	49.15	40.05	40.57	32.94	35.84	34.70	33.80

From: White
To: GoldThreads: 16
TTRT: 8msLLC Buffers: 48K
Single Test**TABLE 42: SINGLE PROCESSOR, 6TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	43.69	31.68	33.55	29.13	29.47	30.13	29.03
12	32.77	30.95	27.31	29.13	21.28	23.01	24.97	22.51
20	95.57	32.77	31.68	33.72	33.72	33.54	34.95	33.52
28	81.92	38.23	34.59	35.89	35.89	35.78	35.57	34.62
36	32.77	49.15	34.59	37.45	33.55	35.42	35.96	35.40
44	105.33	38.23	34.59	36.67	33.72	34.74	34.06	34.41
52	95.57	43.69	34.59	35.89	12.57	12.03	10.84	10.90
60	30.04	36.41	34.59	34.33	6.86	6.52	6.24	6.17

From: Gold
To: WhiteThreads: 16
TTRT: 8msLLC Buffers: 48K
Single Test

TABLE 43: SINGLE PROCESSOR, 7TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	23.67	28.40	23.96	21.84	21.81	21.76	19.39
12	24.58	30.95	24.08	23.60	17.60	18.03	20.25	18.84
20	87.38	30.04	26.03	22.41	26.15	26.58	28.29	30.81
28	30.04	32.77	26.60	24.93	31.45	25.68	29.00	30.81
36	32.77	32.77	36.04	29.30	27.02	27.77	29.50	29.26
44	30.04	36.41	28.24	29.13	28.17	29.14	30.14	29.11
52	30.04	30.95	32.40	29.09	24.96	25.41	30.13	28.46
60	74.22	30.95	29.73	28.37	28.24	25.39	26.77	25.60

From: White
To: GoldThreads: 16
TTRT: 8msLLC Buffers: 48K
Dual Test**TABLE 44: SINGLE PROCESSOR, 8TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	27.31	27.31	29.86	29.72	21.90	19.40	18.04	20.86
12	32.77	25.49	26.94	27.15	18.86	17.60	15.65	16.14
20	30.04	25.49	30.58	28.88	24.93	26.16	24.07	27.03
28	30.04	29.13	30.06	30.65	28.90	25.74	25.32	28.52
36	32.77	38.23	30.95	30.64	23.87	26.27	26.92	29.95
44	63.39	27.31	25.75	34.40	23.72	26.29	27.56	29.50
52	92.84	24.58	32.77	29.44	11.60	11.49	12.76	12.36
60	30.04	32.77	28.52	30.44	6.81	7.29	7.12	7.14

From: Gold
To: WhiteThreads: 16
TTRT: 8msLLC Buffers: 48K
Dual Test**TABLE 45: SINGLE PROCESSOR, 9TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	40.05	35.28	34.33	34.28	33.32	33.84
12	32.77	36.41	31.68	32.33	25.18	25.74	26.67	25.12
36	70.09	43.69	38.23	40.83	38.49	39.99	40.10	40.14
44	163.84	43.69	38.23	40.57	41.61	41.53	41.99	41.84
52	105.33	43.69	43.69	42.65	39.53	42.57	42.26	42.09
60	63.72	38.23	43.69	42.65	40.83	42.01	41.67	41.85
60	32.77	38.23	43.69	43.69	37.71	35.84	37.67	35.03
60	32.77	38.23	40.05	41.87	28.08	31.95	30.55	28.37

From: White
To: GoldThreads: 8
TTRT: 5msLLC Buffers: 48K
Single Test

TABLE 46: SINGLE PROCESSOR, 10TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	37.14	33.72	29.13	28.72	26.90	26.24
12	32.77	30.95	30.58	31.24	25.95	26.49	24.57	25.87
20	32.77	38.23	34.59	35.11	34.90	33.54	33.84	30.69
28	81.92	32.77	36.41	33.72	35.89	32.14	32.43	28.56
36	63.72	38.23	38.23	35.11	31.45	31.36	32.77	27.85
44	32.77	38.23	38.23	35.89	32.23	30.41	32.58	28.65
52	32.77	38.23	36.41	35.89	18.37	16.68	17.16	14.76
60	95.57	32.77	34.59	34.33	10.29	9.33	10.37	10.62

From: Gold
To: WhiteThreads: 8
TTRT: 5msLLC Buffers: 48K
Single Test**TABLE 47: SINGLE PROCESSOR, 11TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	24.58	25.85	27.31	28.37	17.43	22.19	18.28	21.07
12	30.04	26.40	23.69	24.29	17.16	18.86	17.80	18.53
20	24.58	32.77	28.76	31.14	23.90	27.62	26.91	28.62
28	27.31	40.05	26.99	30.69	28.87	28.22	30.12	27.73
36	27.31	30.40	27.67	31.78	27.12	28.88	30.55	27.66
44	30.04	28.22	28.24	32.41	27.48	28.94	29.32	27.23
52	26.40	36.41	31.68	33.41	24.90	26.21	26.51	26.90
60	32.77	25.49	26.94	31.92	25.05	24.15	23.11	26.35

From: White
To: GoldThreads: 8
TTRT: 5msLLC Buffers: 48K
Dual Test**TABLE 48: SINGLE PROCESSOR, 12TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	30.95	29.49	25.93	21.57	20.89	18.25	20.29
12	32.77	25.49	24.45	24.10	21.28	18.79	16.74	19.28
20	23.67	30.95	25.69	29.36	26.48	24.24	24.88	26.26
28	30.04	43.69	24.60	29.68	27.36	26.13	25.99	27.23
36	66.32	24.58	27.12	30.41	31.24	25.13	25.63	27.29
44	90.11	30.95	29.86	30.50	27.36	27.06	27.42	28.61
52	30.04	30.95	27.31	32.94	14.03	13.82	14.52	13.27
60	30.04	27.31	29.13	29.68	7.64	7.39	7.99	7.37

From: Gold
To: WhiteThreads: 8
TTRT: 5msLLC Buffers: 48K
Dual Test

TABLE 49: SINGLE PROCESSOR, 13TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	36.41	35.11	32.94	33.13	32.95	33.14
12	32.77	30.95	36.41	33.24	25.91	27.67	27.67	26.42
20	81.92	49.15	43.69	38.40	39.53	40.33	41.14	40.86
28	105.33	38.23	40.05	42.65	40.57	41.05	42.55	42.66
36	32.77	43.69	43.69	43.69	40.57	42.57	42.26	42.67
44	105.33	49.15	40.05	43.69	40.57	43.13	40.95	42.66
52	105.33	49.15	43.69	44.11	38.40	37.98	39.83	39.73
60	132.18	54.61	41.87	42.65	36.67	34.18	37.50	32.25

From: White
To: GoldThreads: 16
TTRT: 5msLLC Buffers: 48K
Single Test**TABLE 50: SINGLE PROCESSOR, 14TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	36.41	35.89	30.34	29.86	29.55	30.18
12	27.31	32.77	29.49	29.25	25.18	25.72	24.92	24.77
20	191.75	38.23	31.68	35.89	33.72	33.54	34.78	34.86
28	32.77	38.23	34.59	36.67	35.28	34.95	35.39	35.56
36	87.99	43.69	31.68	36.67	33.11	34.95	35.76	36.07
44	32.77	43.69	34.59	35.11	32.16	35.37	35.56	35.29
52	81.92	32.77	32.77	37.45	15.45	15.43	15.98	14.90
60	32.77	32.77	32.77	35.89	8.64	7.45	7.87	7.25

From: Gold
To: WhiteThreads: 16
TTRT: 5msLLC Buffers: 48K
Single Test**TABLE 51: SINGLE PROCESSOR, 15TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	29.13	25.49	24.90	19.39	18.90	20.87	20.88
12	24.38	21.85	24.03	21.71	15.54	15.74	17.77	17.35
20	30.04	27.31	27.51	27.81	25.49	25.35	25.31	25.58
28	30.04	36.41	31.68	23.05	26.24	24.51	27.38	25.99
36	32.77	34.59	28.76	29.54	30.15	25.61	27.72	27.23
44	32.77	41.87	31.68	34.66	31.54	26.63	27.74	27.85
52	30.04	32.77	32.40	29.93	29.98	24.58	25.73	28.30
60	30.04	34.59	29.86	30.20	28.26	22.75	22.52	24.28

From: White
To: GoldThreads: 16
TTRT: 5msLLC Buffers: 48K
Dual Test

TABLE 52: SINGLE PROCESSOR, 16TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	27.31	33.68	25.21	28.53	21.70	19.56	21.78	19.05
12	30.04	28.22	26.42	22.17	22.02	20.35	19.08	19.66
20	30.04	30.95	29.34	25.57	26.82	23.18	23.95	24.41
28	32.77	29.13	24.42	29.13	26.60	24.88	26.10	25.81
36	30.04	36.41	28.76	27.81	25.20	24.02	26.76	25.70
44	24.58	30.95	28.40	27.81	27.76	25.20	26.26	25.67
52	32.77	34.59	26.60	28.87	13.07	14.29	13.63	13.95
60	32.77	29.13	33.37	30.95	7.36	8.01	8.58	8.33

From: Gold
To: WhiteThreads: 16
TTRT: 5msLLC Buffers: 48K
Dual Test**TABLE 53: SINGLE PROCESSOR, 17TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	36.41	36.41	35.89	31.68	33.17	33.32	33.05
12	32.77	32.77	36.41	36.67	27.36	29.96	27.08	27.11
20	168.13	43.69	40.05	38.75	39.33	39.37	39.49	39.90
28	32.77	43.69	40.05	41.61	39.33	43.13	41.00	42.53
36	32.77	32.77	40.05	42.65	41.87	40.41	41.56	42.23
44	163.84	38.23	41.87	39.70	40.83	42.57	43.11	41.78
52	32.77	54.61	41.87	39.79	35.28	34.29	36.22	38.24
60	253.31	43.69	40.05	40.83	29.91	31.85	34.62	30.08

From: White
To: GoldThreads: 8
TTRT: 11msLLC Buffers: 48K
Single Test**TABLE 54: SINGLE PROCESSOR, 18TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	36.41	36.67	31.55	30.01	30.12	29.84
12	32.77	30.95	28.40	27.76	25.45	24.21	23.51	24.12
20	61.44	38.23	34.39	36.67	35.11	34.32	34.40	34.49
28	118.33	32.77	38.23	37.10	35.11	36.25	35.96	35.97
36	32.77	32.77	38.23	35.89	35.89	36.62	35.58	35.76
44	32.77	38.23	36.41	36.67	35.89	35.42	36.20	35.19
52	69.32	32.77	38.23	37.45	16.28	15.68	18.83	14.83
60	32.77	54.61	36.41	35.28	8.92	8.11	8.33	7.13

From: Gold
To: WhiteThreads: 8
TTRT: 11msLLC Buffers: 48K
Single Test

TABLE 55: SINGLE PROCESSOR, 19TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	24.58	21.05	24.90	21.80	21.92	21.04	21.36
12	34.58	30.95	22.26	23.96	18.24	19.59	21.64	18.60
20	32.77	32.77	25.69	26.51	27.29	28.42	27.54	29.22
28	30.04	27.31	26.58	28.24	33.41	26.04	29.59	29.77
36	32.77	27.67	28.76	27.75	33.11	26.92	30.67	29.45
44	70.19	36.41	27.67	28.85	30.15	27.21	28.95	28.32
52	30.04	36.41	36.41	27.05	28.76	26.75	27.56	26.48
60	30.04	34.59	29.86	25.61	30.06	25.97	24.51	23.74

From: White
To: GoldThreads: 8
TTRT: 11msLLC Buffers: 48K
Dual Test**TABLE 56: SINGLE PROCESSOR, 20TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	133.80	30.95	31.31	26.86	23.60	19.96	20.18	21.23
12	32.77	28.22	25.85	26.19	22.68	18.91	16.92	18.46
20	32.77	29.13	28.76	29.72	27.97	22.66	24.06	25.52
28	30.04	27.31	28.24	28.14	28.87	24.44	25.14	28.26
36	90.11	35.50	28.40	29.72	30.36	26.22	24.20	28.82
44	32.77	38.23	29.49	31.14	28.74	24.76	26.79	28.91
52	84.35	27.31	27.51	31.02	14.08	13.99	12.68	13.08
60	29.13	30.95	32.40	29.72	8.80	8.24	7.74	7.60

From: Gold
To: WhiteThreads: 8
TTRT: 11msLLC Buffers: 48K
Dual Test**TABLE 57: SINGLE PROCESSOR, 21ST TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	38.23	34.33	32.16	31.48	31.97	33.17
12	30.04	32.77	32.77	34.50	24.63	27.89	27.05	25.93
20	32.77	43.69	36.41	39.53	36.93	39.43	39.09	39.86
28	136.53	43.69	38.23	40.57	39.01	40.63	39.72	42.11
36	136.53	43.69	41.69	41.61	40.83	39.51	39.00	41.95
44	136.53	38.23	41.87	40.57	39.01	40.53	38.91	41.28
52	32.77	38.23	41.87	41.61	36.58	38.77	33.83	40.30
60	32.77	49.15	38.23	43.69	32.16	31.82	29.90	30.95

From: White
To: GoldThreads: 16
TTRT: 11msLLC Buffers: 48K
Single Test

TABLE 58: SINGLE PROCESSOR, 22ND TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	34.59	36.67	29.13	29.16	29.54	29.35
12	30.04	32.77	32.77	34.33	24.44	24.92	23.94	22.96
20	63.72	38.23	34.59	35.11	33.55	33.86	32.39	33.27
28	29.13	43.69	38.23	37.45	34.33	34.64	34.94	35.17
36	32.77	43.69	38.23	35.89	32.77	34.64	34.61	35.85
44	72.82	32.77	36.41	35.89	33.55	35.37	34.99	35.75
52	32.77	49.15	38.23	35.89	14.02	14.08	14.24	14.37
60	30.04	32.77	38.23	35.89	8.09	7.82	7.03	6.93

From: Gold
To: WhiteThreads: 16
TTRT: 11msLLC Buffers: 48K
Single Test**TABLE 59: SINGLE PROCESSOR, 23RD TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	30.04	29.49	25.57	21.70	19.28	20.61	20.01
12	27.31	27.31	24.24	24.63	18.06	18.14	16.77	16.71
20	27.31	29.13	26.42	23.72	26.53	25.37	24.93	27.40
28	30.04	29.13	29.34	25.57	31.01	28.52	27.70	29.68
36	26.40	38.23	28.76	27.15	30.77	27.12	28.27	27.80
44	32.77	34.59	32.40	30.36	34.66	29.42	29.66	29.73
52	27.31	30.95	31.68	33.67	28.64	27.95	27.30	26.68
60	133.80	34.59	31.68	32.02	25.33	23.90	24.70	24.02

From: White
To: GoldThreads: 16
TTRT: 11msLLC Buffers: 48K
Dual Test**TABLE 60: SINGLE PROCESSOR, 24TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	133.80	40.96	27.67	26.72	22.18	20.34	21.30	20.30
12	30.04	28.22	24.76	25.05	20.82	22.10	20.67	20.47
20	30.04	32.77	29.34	29.27	25.49	28.41	25.45	26.34
28	81.92	29.13	32.77	30.06	25.78	27.02	26.38	26.00
36	32.77	27.31	28.97	28.05	26.55	26.62	25.74	26.12
44	30.04	31.86	34.59	29.96	25.99	27.71	26.01	27.89
52	27.31	29.13	27.15	27.81	15.88	16.08	14.63	16.43
60	30.04	41.87	27.91	29.15	9.39	9.50	8.59	8.95

From: Gold
To: WhiteThreads: 16
TTRT: 11msLLC Buffers: 48K
Dual Test

TABLE 61: SINGLE PROCESSOR, 25TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	87.99	32.77	34.59	35.11	31.55	30.59	31.63	31.83
12	32.77	38.23	32.77	33.72	28.28	30.88	24.70	26.55
20	32.77	43.69	40.05	42.65	41.61	40.41	41.14	40.33
28	32.77	32.77	40.05	41.87	43.69	42.01	42.35	42.38
36	105.33	43.69	41.87	42.65	43.69	42.57	41.67	42.09
44	81.92	43.69	41.87	41.61	41.61	41.45	42.23	42.23
52	32.77	49.15	43.69	40.83	38.75	37.38	39.35	38.44
60	32.77	49.15	40.05	41.61	35.89	35.11	34.75	30.13

From: White
To: GoldThreads: 8
TTRT: 25msLLC Buffers: 48K
Single Test**TABLE 62: SINGLE PROCESSOR, 26TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	32.77	34.33	29.13	29.16	29.43	29.34
12	32.77	30.95	31.68	31.55	26.55	26.01	27.20	25.66
20	79.19	32.77	32.77	36.67	34.33	34.22	34.58	33.04
28	72.82	36.41	36.41	37.45	35.89	35.78	35.57	34.96
36	32.77	32.77	32.77	35.28	34.33	35.42	35.96	35.46
44	32.77	32.77	34.59	36.67	34.33	35.37	34.87	35.06
52	32.77	32.77	34.59	37.45	19.49	17.71	17.49	16.59
60	32.77	32.77	35.32	34.33	8.42	8.54	8.36	8.31

From: Gold
To: WhiteThreads: 8
TTRT: 25msLLC Buffers: 48K
Single Test**TABLE 63: SINGLE PROCESSOR, 27TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	27.31	26.40	25.33	23.65	20.05	19.52	20.50	17.46
12	30.04	21.30	23.30	23.39	21.25	17.41	15.30	15.28
20	27.31	32.77	31.16	25.99	30.22	24.39	22.45	26.98
28	27.31	28.22	30.43	25.94	32.23	26.52	27.08	29.58
36	30.04	47.33	28.76	27.15	32.94	28.14	27.63	29.92
44	32.77	28.22	30.95	33.11	31.63	30.47	30.05	30.40
52	30.04	36.41	35.32	32.80	27.39	30.66	27.91	27.93
60	102.60	38.23	29.49	31.75	25.66	29.02	25.58	23.69

From: White
To: GoldThreads: 8
TTRT: 25msLLC Buffers: 48K
Dual Test

TABLE 64: SINGLE PROCESSOR, 28TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	78.28	27.31	27.12	26.99	17.36	20.76	21.53	20.65
12	32.77	32.77	24.27	25.21	21.19	21.80	19.80	20.10
20	32.77	27.67	28.61	28.76	24.46	24.38	24.76	26.12
28	32.77	34.59	24.21	27.15	28.14	26.36	26.74	26.47
36	30.04	29.13	29.49	25.17	26.96	25.85	26.93	25.70
44	32.77	30.95	25.85	29.99	25.99	26.06	27.33	26.33
52	67.36	24.38	27.16	28.74	15.88	15.51	14.99	14.10
60	95.37	30.95	28.24	29.56	8.73	8.66	8.49	8.91

From: Gold
To: White

Threads: 8
TTRT: 25ms

LLC Buffers: 48K
Dual Test

TABLE 65: SINGLE PROCESSOR, 29TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	34.59	35.89	31.68	32.49	32.79	32.14
12	32.77	32.77	34.59	32.33	27.48	29.08	28.00	26.95
20	32.77	43.69	40.05	40.57	39.53	41.45	40.60	40.86
28	105.33	43.69	43.69	40.57	40.57	42.01	41.67	41.67
36	81.92	43.69	41.87	43.69	40.83	40.41	41.94	41.83
44	135.62	49.15	43.69	42.65	41.61	41.53	42.33	42.24
52	30.04	49.15	43.69	42.65	32.94	38.39	37.68	36.14
60	81.92	49.15	41.87	43.69	35.11	35.39	33.86	30.88

From: White
To: Gold

Threads: 16
TTRT: 25ms

LLC Buffers: 48K
Single Test

TABLE 66: SINGLE PROCESSOR, 30TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	34.59	35.89	29.13	29.78	29.84	30.32
12	32.77	32.77	29.49	32.16	27.27	26.78	26.37	24.84
20	32.77	38.23	34.59	35.11	35.11	33.90	34.76	34.39
28	32.77	38.23	34.59	37.45	36.67	36.20	35.96	35.41
36	32.77	43.69	34.59	35.11	35.89	36.20	35.38	35.46
44	32.77	49.15	34.59	35.89	35.89	35.78	35.97	35.96
52	69.32	43.69	38.23	36.67	16.94	15.80	15.77	16.73
60	32.77	30.95	34.59	36.67	7.85	8.08	8.53	7.31

From: Gold
To: White

Threads: 16
TTRT: 25ms

LLC Buffers: 48K
Single Test

TABLE 67: SINGLE PROCESSOR, 31ST TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	24.58	29.13	27.31	27.12	25.21	21.11	18.25	20.21
12	110.14	27.31	25.69	24.44	20.41	19.38	19.74	19.99
20	30.04	22.76	33.90	29.68	28.33	29.28	28.41	27.24
28	24.58	33.13	23.87	27.35	29.82	31.37	30.80	29.15
36	32.77	29.13	30.95	33.70	29.63	32.85	29.96	28.01
44	30.04	30.95	28.40	32.91	32.63	30.73	29.57	28.26
52	32.77	38.23	30.58	32.49	26.44	26.24	26.29	27.34
60	30.04	25.49	28.42	29.06	26.27	25.55	23.73	25.90

From: White
To: GoldThreads: 16
TTRT: 25msLLC Buffers: 48K
Dual Test**TABLE 68: SINGLE PROCESSOR, 32ND TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	31.86	28.03	26.75	20.72	19.48	19.31	19.47
12	27.31	29.13	26.21	24.13	20.00	16.33	17.72	18.47
20	23.67	30.95	27.70	29.02	27.03	25.25	25.38	24.82
28	30.04	28.22	31.16	30.23	28.42	26.06	25.82	25.73
36	23.67	29.13	30.06	28.50	26.68	26.97	25.30	27.19
44	27.31	30.95	31.68	28.80	27.06	27.23	26.22	27.90
52	87.99	27.31	25.33	29.14	15.18	14.30	14.79	14.26
60	21.85	29.13	27.67	30.13	7.79	8.34	8.33	7.93

From: Gold
To: WhiteThreads: 16
TTRT: 25msLLC Buffers: 48K
Dual Test**TABLE 69: SINGLE PROCESSOR, 33RD TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	38.23	38.11	32.33	32.48	32.39	33.48
12	32.77	43.69	44.85	34.58	27.12	29.79	31.83	27.60
20	137.14	54.61	43.69	39.53	39.53	39.37	41.16	44.22
28	69.32	34.95	41.87	39.79	41.61	46.97	42.82	41.54
36	32.77	32.77	41.87	42.65	46.83	46.89	46.93	39.95
44	87.99	43.69	43.69	43.69	31.05	33.05	35.01	35.42
52	32.77	49.15	41.87	39.61	15.12	12.40	14.07	13.06
60	69.32	36.41	44.85	41.61	13.01	11.07	12.96	13.06

From: White
To: GoldThreads: 8
TTRT: 8msLLC Buffers: 48K
Single Test, FDDI Boards Switched

TABLE 70: SINGLE PROCESSOR, 34TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	34.23	36.41	32.77	28.16	28.64	28.86	29.13
12	32.77	34.23	36.58	31.12	28.13	28.72	29.77	28.56
20	32.77	32.77	32.77	32.77	32.77	34.22	33.48	33.05
28	72.82	34.23	34.59	35.11	31.35	33.13	32.33	33.35
36	32.77	32.77	36.41	35.89	22.50	25.98	23.71	23.74
44	32.77	34.95	31.68	32.44	6.76	5.51	6.35	5.66
52	17.29	26.39	21.87	22.77	4.11	4.17	4.22	3.91
60	11.39	12.56	14.59	17.10	3.54	3.48	3.48	3.51

From: Gold
To: White

Threads: 8
TTRT: 8ms

LLC Buffers: 48K
Single Test, FDDI Boards Switched

APPENDIX E: NTCPP TWO PROCESSORS RESULTS

TABLE 71: PARAMETERS USED FOR TWO PROCESSOR TEST

Test Number	From:	To:	NFS_asynch_threads	TTRT	sbf_num_pk_rx	sbf_mtu
1st Test	White	Gold	8	8ms	48K	4352
2nd Test	White	Gold	16	8ms	48K	4352
3rd Test	White	Gold	8	5ms	48K	4352
4th Test	White	Gold	16	5ms	48K	4352
5th Test	White	Gold	8	11ms	48K	4352
6th Test	White	Gold	16	11ms	48K	4352
7th Test	White	Gold	8	25ms	48K	4352
8th Test	White	Gold	16	25ms	48K	4352
9th Test	White	Gold	8	8ms	56K	4352
10th Test	White	Gold	16	8ms	56K	4352
11th Test	White	Gold	8	5ms	56K	4352
12th Test	White	Gold	16	5ms	56K	4352
13th Test	White	Gold	8	11ms	56K	4352
14th Test	White	Gold	16	11ms	56K	4352
15th Test	White	Gold	8	25ms	56K	4352
16th Test	White	Gold	16	25ms	56K	4352
17th Test	White	Gold	8	8ms	40K	4352
18th Test	White	Gold	16	8ms	40K	4352
19th Test	White	Gold	8	5ms	40K	4352
20th Test	White	Gold	16	5ms	40K	4352
21st Test	White	Gold	8	11ms	40K	4352
22nd Test	White	Gold	16	11ms	40K	4352
23rd Test	White	Gold	8	25ms	40K	4352
24th Test	White	Gold	16	25ms	40K	4352
25th Test	White	Gold	8	8ms	48K	4192
26th Test	White	Gold	16	8ms	48K	4192
27th Test	White	Gold	8	5ms	48K	4192
28th Test	White	Gold	16	5ms	48K	4192
29th Test	White	Gold	8	11ms	48K	4192

TABLE 71: PARAMETERS USED FOR TWO PROCESSOR TEST

Test Number	From:	To:	NFS_asynch_threads	TTRT	sbf_num_llc_rx	sbf_mtu
30th Test	White	Gold	16	11ms	48K	4192
31st Test	White	Gold	8	25ms	48K	4192
32nd Test	White	Gold	16	25ms	48K	4192
33rd Test	White	Gold	8	8ms	56K	4192
34th Test	White	Gold	16	8ms	56K	4192
35th Test	White	Gold	8	5ms	56K	4192
36th Test	White	Gold	16	5ms	56K	4192
37th Test	White	Gold	8	11ms	56K	4192
38th Test	White	Gold	16	11ms	56K	4192
39th Test	White	Gold	8	25ms	56K	4192
40th Test	White	Gold	16	25ms	56K	4192
41st Test	White	Gold	8	8ms	40K	4192
42nd Test	White	Gold	16	8ms	40K	4192
43rd Test	White	Gold	8	5ms	40K	4192
44th Test	White	Gold	16	5ms	40K	4192
45th Test	White	Gold	8	11ms	40K	4192
46th Test	White	Gold	16	11ms	40K	4192
47th Test	White	Gold	8	25ms	40K	4192
48th Test	White	Gold	16	25ms	40K	4192

TABLE 72: TWO PROCESSORS, 1ST TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	32.77	32.77	32.77	30.34	31.80	30.71	31.06
12	30.04	32.77	31.31	29.37	30.46	30.34	30.43	30.86
20	353.17	60.07	54.61	54.61	50.97	52.43	50.84	51.36
28	746.38	54.61	58.25	58.98	49.52	52.43	52.47	52.88
36	105.33	60.07	54.61	55.34	50.97	50.84	52.47	53.12
44	32.77	49.15	58.25	52.43	49.52	51.63	52.52	53.33
52	32.77	43.69	50.97	56.80	48.06	51.63	52.06	52.28
60	502.44	54.61	50.97	53.16	50.97	46.71	50.80	47.17

From: White
To: Gold

Threads: 8
TTRT: 8ms

LLC Buffers: 48K
MTU: 4352 Bytes

TABLE 73: TWO PROCESSORS, 2ND TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	33.55	31.55	31.16	31.77	31.54
12	27.31	32.77	29.49	30.95	31.55	29.98	30.27	30.69
20	32.77	54.61	50.97	50.97	49.52	51.63	50.76	52.22
28	32.77	60.07	54.61	53.16	50.97	51.63	52.47	51.68
36	266.70	60.07	47.33	55.34	50.97	52.61	52.89	52.88
44	367.47	54.61	47.33	54.61	50.97	54.55	52.52	53.60
52	240.30	60.07	50.97	58.98	48.06	53.40	50.76	52.25
60	32.77	49.15	43.69	50.97	49.52	49.25	52.10	44.91

From: White
To: Gold

Threads: 16
TTRT: 8ms

LLC Buffers: 48K
MTU: 4352 Bytes

TABLE 74: TWO PROCESSORS, 3RD TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	35.11	30.95	32.13	31.46	31.70
12	30.04	30.95	30.58	30.95	30.34	30.55	31.02	30.55
20	118.33	60.07	58.25	54.61	52.43	50.05	49.59	50.97
28	573.44	43.69	58.25	52.43	52.43	51.63	51.60	51.21
36	32.77	43.69	58.25	52.43	50.97	54.37	52.89	53.11
44	303.10	60.07	58.25	56.80	49.52	51.63	52.52	52.67
52	385.93	60.07	54.61	53.16	47.02	50.05	49.59	50.70
60	95.57	54.61	50.97	56.80	49.20	47.79	44.75	44.41

From: White
To: Gold

Threads: 8
TTRT: 5ms

LLC Buffers: 48K
MTU: 4352 Bytes

TABLE 75: TWO PROCESSORS, 4TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	32.77	32.16	31.48	31.95	32.18
12	32.77	32.77	30.58	31.68	31.24	31.20	34.76	31.95
20	458.49	54.61	50.97	56.80	50.97	52.61	52.09	52.25
28	95.57	54.61	54.61	54.61	53.16	52.43	53.35	51.89
36	136.53	65.54	54.61	56.80	50.97	52.61	55.70	54.48
44	32.77	60.07	58.25	53.16	52.43	51.63	53.39	53.56
52	249.40	43.69	58.25	56.80	48.06	50.84	50.42	52.23
60	281.91	49.15	54.61	58.98	48.06	50.84	47.54	46.71

From: White
To: Gold

Threads: 16
TTRT: 5ms

LLC Buffers: 48K
MTU: 4352 Bytes

TABLE 76: TWO PROCESSORS, 5TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	32.77	32.77	34.33	30.95	31.16	31.95	31.44
12	27.31	27.31	30.58	30.95	33.01	29.16	30.45	30.18
20	230.94	60.07	58.25	53.16	46.60	50.18	51.60	50.35
28	32.77	60.07	54.61	52.43	52.43	50.18	51.64	51.80
36	32.77	54.61	54.61	54.61	53.16	48.82	52.47	52.68
44	398.68	41.87	54.61	61.17	52.43	52.43	52.52	52.08
52	136.53	38.23	54.61	54.61	51.70	51.81	50.08	51.45
60	32.77	54.61	58.25	54.61	52.12	47.54	46.37	45.30

From: White
To: GoldThreads: 8
TTRT: 11msLLC Buffers: 48K
MTU: 4352 Bytes**TABLE 77: TWO PROCESSORS, 6TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	30.95	34.59	33.55	32.16	32.45	32.11	32.10
12	27.31	30.95	31.68	32.16	30.95	32.13	30.86	31.23
20	100.37	54.61	54.61	56.80	52.43	51.63	50.80	51.25
28	163.84	49.15	58.25	56.80	54.61	52.43	50.80	52.92
36	190.89	49.15	54.61	58.98	53.16	51.02	49.46	52.75
44	435.74	65.54	58.25	56.80	52.43	50.84	53.01	54.06
52	476.96	60.07	54.61	54.61	51.70	47.78	48.07	52.67
60	136.53	49.15	54.61	55.34	50.97	49.52	47.77	48.14

From: White
To: GoldThreads: 16
TTRT: 11msLLC Buffers: 48K
MTU: 4352 Bytes**TABLE 78: TWO PROCESSORS, 7TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	33.55	32.16	32.13	32.27	32.19
12	30.04	32.77	29.49	29.73	30.34	31.85	31.97	31.41
20	32.77	60.07	47.33	53.16	49.52	51.63	52.06	50.21
28	87.99	54.61	47.33	54.61	49.52	53.40	51.22	52.25
36	425.98	49.15	47.33	54.61	50.97	55.34	51.18	52.71
44	32.77	43.69	50.97	53.16	50.97	54.37	53.39	51.84
52	209.09	60.07	54.61	52.43	49.52	47.23	50.47	49.44
60	32.77	60.07	54.61	56.80	48.48	48.03	43.29	44.33

From: White
To: GoldThreads: 8
TTRT: 25msLLC Buffers: 48K
MTU: 4352 Bytes

TABLE 79: TWO PROCESSORS, 8TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	32.77	32.77	34.33	32.77	31.16	31.94	31.86
12	32.77	30.95	33.50	32.16	31.73	30.59	31.49	31.87
20	222.09	60.07	54.61	50.97	52.43	52.61	52.43	51.26
28	95.57	54.61	58.25	56.80	54.61	51.81	53.85	53.10
36	32.77	43.69	50.97	58.98	53.16	50.05	52.60	54.26
44	191.75	54.61	50.97	54.61	49.93	52.78	53.47	53.40
52	32.77	60.07	50.97	53.16	45.56	50.18	49.66	53.37
60	313.12	60.07	47.33	54.61	44.52	51.02	51.26	47.16

From: White
To: Gold

Threads: 16
TTRT: 25ms

LLC Buffers: 48K
MTU: 4352 Bytes

TABLE 80: TWO PROCESSORS, 9TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	33.55	30.95	31.48	31.94	32.03
12	32.77	29.13	31.31	29.37	30.34	30.66	31.32	30.72
20	32.77	54.61	58.25	48.06	49.52	50.84	48.80	49.98
28	226.65	60.07	61.90	49.52	49.52	50.05	48.84	50.97
36	240.30	54.61	54.61	55.34	50.24	49.25	50.46	50.70
44	118.33	60.07	50.97	54.61	46.60	46.57	47.50	48.41
52	178.40	54.61	54.61	53.16	39.44	35.62	40.79	38.74
60	163.84	49.15	54.61	52.43	30.22	26.43	28.45	24.03

From: White
To: Gold

Threads: 8
TTRT: 8ms

LLC Buffers: 56K
MTU: 4352 Bytes

TABLE 81: TWO PROCESSORS, 10TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	34.33	32.16	32.13	32.27	32.79
12	32.77	29.13	31.68	31.55	32.94	31.80	32.17	31.47
20	136.53	60.07	58.25	56.80	50.97	50.84	52.93	51.27
28	862.63	60.07	61.90	52.43	53.16	53.58	52.93	52.88
36	289.45	65.54	54.61	56.80	52.43	53.40	52.98	54.04
44	32.77	60.07	50.97	56.80	45.15	51.02	53.01	52.32
52	105.33	49.15	50.97	54.61	40.05	44.35	43.05	43.66
60	118.33	49.15	47.33	56.80	35.46	36.32	30.46	30.52

From: White
To: Gold

Threads: 16
TTRT: 8ms

LLC Buffers: 56K
MTU: 4352 Bytes

TABLE 82: TWO PROCESSORS, 11TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	34.59	34.33	31.55	32.13	32.11	31.86
12	30.04	29.13	29.49	29.25	29.73	31.16	30.58	31.01
20	300.37	65.54	47.33	50.97	49.52	50.05	51.22	50.98
28	340.42	49.15	54.61	56.80	50.97	50.97	52.93	51.61
36	357.72	60.07	58.25	56.80	54.61	50.84	53.01	52.46
44	404.14	49.15	54.61	52.43	52.43	52.43	51.33	53.11
52	118.33	49.15	50.97	52.43	44.52	45.12	43.11	44.36
60	136.53	60.07	54.61	56.80	46.78	32.39	34.31	27.51

From: White
To: Gold

Threads: 8
TTRT: 5ms

LLC Buffers: 56K
MTU: 4352 Bytes

TABLE 83: TWO PROCESSORS, 12TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	30.95	34.59	33.55	32.16	31.80	31.47	32.11
12	30.04	32.77	30.58	28.64	30.34	30.55	30.70	30.48
20	87.99	65.54	50.97	52.43	49.52	50.84	51.18	50.96
28	209.09	54.61	50.97	56.80	52.43	53.40	53.39	52.66
36	32.77	43.69	58.25	52.43	50.97	51.81	52.47	52.33
44	209.09	49.15	61.90	52.43	51.70	49.38	52.43	49.68
52	267.61	49.15	54.61	54.61	37.97	40.27	43.53	41.02
60	136.53	49.15	47.33	52.43	38.77	35.34	27.04	28.61

From: White
To: Gold

Threads: 16
TTRT: 5ms

LLC Buffers: 56K
MTU: 4352 Bytes

TABLE 84: TWO PROCESSORS, 13TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	34.33	32.16	31.80	31.62	31.54
12	32.77	29.13	30.58	29.37	30.34	31.48	31.15	30.84
20	105.33	49.15	54.61	54.61	48.06	53.40	52.06	51.40
28	240.69	60.07	61.90	52.43	48.06	53.40	50.31	52.01
36	136.53	60.07	54.61	61.17	52.43	52.43	52.47	51.29
44	199.34	43.69	54.61	53.16	50.24	50.97	50.65	50.97
52	32.77	38.23	50.97	53.16	39.43	42.37	42.94	37.45
60	295.52	43.69	50.97	53.16	37.99	30.91	27.44	26.73

From: White
To: Gold

Threads: 8
TTRT: 11ms

LLC Buffers: 56K
MTU: 4352 Bytes

TABLE 85: TWO PROCESSORS, 14TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	30.95	34.59	33.55	31.55	31.16	31.15	31.54
12	136.53	29.13	28.40	30.34	29.73	30.01	30.88	30.34
20	195.33	54.61	50.97	50.97	48.06	50.84	50.76	50.03
28	60.07	54.61	56.80	48.48	50.84	51.18	49.72	
36	49.15	50.97	56.80	50.97	50.84	51.68	51.31	
44	731.56	49.15	49.15	52.43	50.97	51.63	51.26	50.63
52	249.40	60.07	58.25	56.80	41.25	42.93	46.08	44.73
60	32.77	60.07	50.97	50.97	50.66	42.39	32.90	31.35

From: White
To: Gold

Threads: 16
TTRT: 11ms

LLC Buffers: 56K
MTU: 4352 Bytes

TABLE 86: TWO PROCESSORS, 15TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	38.23	32.77	33.55	32.16	31.80	31.46	32.03
12	32.77	36.41	29.49	29.13	31.55	30.55	29.69	30.56
20	199.34	54.61	43.69	52.43	48.06	49.25	50.14	50.95
28	340.42	54.61	47.33	52.43	50.97	52.61	52.06	50.98
36	340.42	60.07	47.33	56.80	49.52	52.43	51.60	51.11
44	136.53	43.69	50.97	50.97	49.52	49.25	49.35	51.63
52	163.84	49.15	47.33	54.61	41.87	37.63	40.21	40.91
60	136.53	49.15	54.61	52.43	32.86	30.63	28.04	26.21

From: White
To: Gold

Threads: 8
TTRT: 25ms

LLC Buffers: 56K
MTU: 4352 Bytes

TABLE 87: TWO PROCESSORS, 16TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	27.31	30.95	34.59	33.55	30.34	31.80	31.65	31.39
12	30.04	30.95	30.58	29.37	29.86	30.27	30.43	30.35
20	204.73	54.61	50.97	52.43	47.02	49.38	49.38	47.82
28	95.57	38.23	50.97	54.61	49.52	50.84	51.79	49.47
36	32.77	49.15	50.97	56.80	52.43	50.18	51.67	50.90
44	209.35	54.61	49.15	53.16	50.97	49.13	48.88	48.58
52	105.33	60.07	49.15	56.80	39.79	35.18	40.48	39.56
60	222.09	60.07	52.79	54.61	43.71	27.27	31.75	28.45

From: White
To: Gold

Threads: 16
TTRT: 25ms

LLC Buffers: 56K
MTU: 4352 Bytes

TABLE 88: TWO PROCESSORS, 17TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	35.11	32.33	32.13	31.77	31.46
12	27.31	30.95	29.49	30.46	30.95	31.16	30.56	30.85
20	95.57	54.61	54.61	56.80	48.06	52.43	50.08	50.35
28	875.63	49.15	54.61	52.43	48.06	50.84	50.49	49.55
36	267.61	60.07	58.25	56.80	34.88	31.68	31.52	29.14
44	105.33	60.07	43.69	50.97	16.61	16.03	15.43	13.97
52	32.77	43.69	45.51	42.29	10.42	10.39	10.46	10.47
60	202.07	29.13	26.21	28.50	15.76	9.98	8.60	8.61

From: White
To: Gold

Threads: 8
TTRT: 8ms

LLC Buffers: 40K
MTU: 4352 Bytes

TABLE 89: TWO PROCESSORS, 18TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	34.59	33.55	30.95	31.80	31.63	31.46
12	27.31	29.13	27.31	28.64	30.95	30.37	30.14	30.93
20	143.21	49.15	47.33	56.80	49.52	50.84	50.01	51.82
28	363.18	38.23	50.97	52.43	48.06	50.05	51.64	51.79
36	32.77	49.15	58.25	54.61	35.49	37.72	33.86	34.20
44	385.93	54.61	54.61	48.06	20.25	19.47	18.16	16.44
52	137.14	47.33	41.87	46.60	15.49	12.22	13.52	12.28
60	27.31	31.86	40.78	35.54	27.72	14.27	11.82	10.84

From: White
To: Gold

Threads: 16
TTRT: 8ms

LLC Buffers: 40K
MTU: 4352 Bytes

TABLE 90: TWO PROCESSORS, 19TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	32.77	32.77	35.11	32.77	32.13	31.63	31.62
12	32.77	29.13	27.31	29.25	32.94	30.34	29.98	30.33
20	1017.63	54.61	54.61	52.43	50.97	50.97	48.11	49.98
28	240.30	49.15	54.61	54.61	49.52	49.25	50.76	49.29
36	32.77	43.69	54.61	52.43	37.36	27.66	33.78	29.93
44	236.35	60.07	50.97	55.34	17.61	17.01	15.02	15.97
52	163.84	38.23	45.51	47.02	13.82	12.60	11.30	11.01
60	24.58	41.87	34.22	40.21	10.92	9.22	9.88	9.02

From: White
To: Gold

Threads: 8
TTRT: 5ms

LLC Buffers: 40K
MTU: 4352 Bytes

TABLE 91: TWO PROCESSORS, 20TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	32.77	32.77	33.55	32.16	31.80	32.44	31.94
12	32.77	29.13	32.40	32.33	30.95	31.48	32.60	32.28
20	95.57	60.07	54.61	55.34	50.97	52.61	51.64	51.81
28	163.84	49.15	54.61	58.98	52.43	51.81	52.47	52.11
36	580.72	49.15	61.90	57.53	42.70	42.85	41.20	42.48
44	408.39	60.07	58.25	52.43	24.17	23.76	22.88	24.98
52	136.53	49.15	52.79	49.52	21.30	16.31	15.64	14.92
60	161.11	45.51	45.51	44.52	34.37	22.15	11.93	13.02

From: White
To: Gold

Threads: 16
TTRT: 5ms

LLC Buffers: 40K
MTU: 4352 Bytes

TABLE 92: TWO PROCESSORS, 21ST TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	29.13	34.59	33.55	30.95	30.84	31.46	31.07
12	27.31	29.13	28.40	29.25	29.86	30.27	29.85	30.25
20	163.84	60.07	50.97	54.61	50.97	50.41	48.11	50.97
28	155.65	54.61	50.97	53.16	49.52	49.14	50.54	49.60
36	32.77	54.61	54.61	52.43	38.21	39.04	38.28	39.86
44	300.37	38.23	50.97	54.61	20.70	22.40	20.85	19.60
52	237.57	36.41	49.15	55.34	15.74	14.62	13.49	12.56
60	32.77	36.41	38.23	39.43	28.27	16.50	11.57	10.39

From: White
To: Gold

Threads: 8
TTRT: 11ms

LLC Buffers: 40K
MTU: 4352 Bytes

TABLE 93: TWO PROCESSORS, 22ND TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	34.59	33.55	32.77	31.80	31.95	31.86
12	24.58	30.95	29.49	29.73	29.25	30.55	30.87	31.00
20	32.77	49.15	58.25	52.43	50.97	51.63	53.35	52.44
28	357.72	60.07	61.90	54.61	49.52	51.63	53.39	52.02
36	209.35	60.07	58.25	52.43	37.97	35.63	38.66	35.97
44	136.53	60.07	50.97	52.12	21.22	19.94	19.19	17.06
52	99.86	34.59	40.05	52.12	14.32	13.29	13.40	11.85
60	27.31	41.87	37.87	52.12	25.79	11.10	10.54	10.27

From: White
To: Gold

Threads: 16
TTRT: 11ms

LLC Buffers: 40K
MTU: 4352 Bytes

TABLE 94: TWO PROCESSORS, 23RD TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	33.55	32.77	31.48	31.94	32.19
12	27.31	29.13	30.58	28.16	31.55	30.55	30.88	30.84
20	163.84	43.69	58.25	54.61	50.97	48.59	50.01	50.37
28	163.84	60.07	58.25	54.61	49.52	46.81	51.26	50.46
36	236.40	60.07	61.90	54.61	40.21	30.18	32.97	36.09
44	226.65	49.15	54.61	49.52	17.11	18.16	18.16	17.45
52	163.84	40.05	38.96	42.03	13.61	12.51	13.09	11.21
60	133.80	34.59	32.77	38.70	12.96	13.13	10.77	11.18

From: White
To: Gold

Threads: 8
TTRT: 25ms

LLC Buffers: 40K
MTU: 4352 Bytes

TABLE 95: TWO PROCESSORS, 24TH TEST RESULTS

Window Size (K bytes)	File A Mbps.	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	43.69	32.77	34.33	31.55	31.48	31.46	31.38
12	30.04	27.31	30.58	30.34	30.34	30.55	29.84	30.70
20	370.05	43.69	58.25	49.62	49.52	45.58	49.93	50.96
28	99.86	60.07	50.97	39.32	35.37	31.76	33.59	31.37
36	105.33	43.69	46.97	38.35	19.35	20.65	19.89	19.76
44	22.76	37.14	34.59	24.52	10.91	11.70	10.42	9.39
52	84.65	24.76	26.21	19.58	9.58	8.59	8.83	7.65
60	22.76	26.76	18.98	18.03	8.01	8.58	7.65	6.35

From: White
To: Gold

Threads: 16
TTRT: 25ms

LLC Buffers: 40K
MTU: 4352 Bytes

TABLE 96: TWO PROCESSORS, 25TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	34.59	37.45	35.11	36.20	36.16	36.16
12	27.31	27.31	27.31	26.79	28.76	27.93	28.74	27.94
20	209.09	43.69	54.61	52.43	49.52	50.05	50.39	50.47
28	209.35	54.61	58.25	54.61	50.97	51.63	52.52	54.02
36	313.12	54.61	54.61	52.43	50.66	53.40	51.64	53.81
44	32.77	32.77	38.23	48.06	42.29	45.18	40.85	43.08
52	62.39	24.58	31.37	33.72	27.15	34.44	28.68	25.57
60	23.67	16.12	27.03	25.75	36.43	34.19	21.90	20.40

From: White
To: Gold

Threads: 8
TTRT: 8ms

LLC Buffers: 48K
MTU: 4192 Bytes

TABLE 97: TWO PROCESSORS 26TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	36.41	34.33	36.67	36.20	36.37	36.58
12	27.31	25.49	24.03	25.91	28.76	27.23	28.88	28.26
20	57.344	54.61	47.33	49.52	53.16	46.04	50.88	49.85
28	411.42	54.61	47.33	49.52	50.97	50.35	52.06	54.49
36	105.33	49.15	45.51	53.16	49.52	50.10	51.60	51.79
44	32.77	36.41	40.78	44.52	45.56	41.09	42.08	41.80
52	25.49	24.32	28.61	29.94	22.45	28.66	26.59	28.23
60	15.93	25.40	28.76	21.53	15.90	18.60	18.59	18.05

From: White
To: GoldThreads: 16
TTRT: 8msLLC Buffers: 48K
MTU: 4192 Bytes**TABLE 98: TWO PROCESSORS, 27TH TEST RESULT7**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	43.69	36.41	37.45	33.55	36.20	35.96	36.06
12	27.31	25.49	25.49	25.91	29.25	30.59	29.28	29.70
20	32.77	54.61	50.97	52.43	50.97	52.61	51.60	51.63
28	115.60	54.61	52.79	49.93	52.43	54.55	52.98	54.73
36	32.77	54.61	52.43	43.74	44.18	49.62	46.53	45.11
44	161.11	24.58	37.18	34.74	34.59	36.42	33.22	30.57
52	106.04	25.49	18.70	28.65	27.51	26.02	23.55	21.87
60	23.21	15.58	16.90	24.43	20.91	18.08	17.50	13.09

From: White
To: GoldThreads: 8
TTRT: 5msLLC Buffers: 48K
MTU: 4192 Bytes**TABLE 99: TWO PROCESSORS, 28TH TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	43.69	34.59	37.45	35.89	35.78	36.19	35.67
12	27.31	25.49	25.49	25.02	29.73	29.16	28.40	28.50
20	118.33	60.07	54.61	50.97	49.52	50.84	51.60	52.23
28	32.77	49.15	54.61	54.61	52.43	51.81	52.06	52.89
36	209.09	49.15	50.97	50.97	49.52	51.15	52.98	50.41
44	372.93	49.15	47.33	50.97	41.68	46.47	42.04	44.85
52	23.67	36.41	38.23	36.90	31.12	28.00	28.46	27.17
60	24.58	21.30	19.93	26.06	28.48	22.34	20.34	19.24

From: White
To: GoldThreads: 16
TTRT: 5msLLC Buffers: 48K
MTU: 4192 Bytes

TABLE 100: TWO PROCESSORS, 29TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	43.69	36.41	36.67	35.89	35.37	35.96	35.95
12	27.31	25.49	26.58	25.57	29.37	28.26	27.75	29.15
20	163.84	60.07	47.33	50.97	48.06	48.72	50.87	52.02
28	87.99	54.61	54.61	49.52	49.52	49.25	51.00	53.91
36	32.77	49.15	49.15	53.16	49.52	49.25	52.61	53.38
44	233.62	32.77	40.05	42.03	39.86	42.85	43.83	44.70
52	27.31	28.22	30.58	34.05	27.88	26.02	28.30	30.98
60	14.11	20.21	25.30	22.95	19.72	20.17	25.32	18.62

From: White
To: Gold

Threads: 8
TTRT: 11ms

LLC Buffers: 48K
MTU: 4192 Bytes

TABLE 101: TWO PROCESSORS, 30TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	72.82	32.77	40.05	36.67	34.33	35.37	36.37	36.47
12	24.58	27.31	26.21	25.82	28.64	29.07	29.02	28.77
20	144.73	54.61	47.33	52.43	49.52	50.35	52.01	52.25
28	87.99	54.61	50.97	49.52	53.16	51.63	54.27	55.44
36	294.91	49.15	41.87	49.20	49.93	53.58	54.27	52.24
44	92.84	43.69	36.04	40.15	40.64	45.91	45.30	42.43
52	23.67	27.31	21.20	35.08	26.25	34.25	32.36	28.54
60	22.76	19.48	22.44	20.04	16.91	21.30	17.75	17.78

From: White
To: Gold

Threads: 16
TTRT: 11ms

LLC Buffers: 48K
MTU: 4192 Bytes

TABLE 102: TWO PROCESSORS, 31ST TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	43.69	38.23	36.67	36.67	35.78	35.96	36.37
12	24.58	29.13	26.58	25.82	27.19	28.96	28.90	29.14
20	118.33	54.61	50.97	52.43	50.97	50.18	52.43	50.83
28	406.87	49.15	50.97	52.43	52.43	52.78	54.31	52.50
36	163.84	38.23	54.61	53.16	50.24	55.52	52.19	54.73
44	118.33	41.87	40.05	45.56	45.56	48.46	44.18	46.00
52	155.65	26.40	32.77	33.11	31.85	36.02	31.40	30.01
60	19.11	37.14	25.91	21.77	36.17	27.44	19.58	21.12

From: White
To: Gold

Threads: 16
TTRT: 5ms

LLC Buffers: 48K
MTU: 4192 Bytes

TABLE 103: TWO PROCESSORS, 32ND TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	105.33	32.77	32.77	35.89	36.67	35.78	35.76	35.75
12	27.31	27.31	24.76	26.79	28.76	28.39	29.19	29.01
20	163.84	60.07	58.25	49.52	52.43	50.84	52.43	51.26
28	118.33	60.07	58.25	52.43	52.43	51.81	52.52	52.29
36	423.25	43.69	58.25	50.97	50.97	53.40	50.85	52.66
44	27.31	43.69	43.69	46.60	41.61	19	40.60	43.53
52	105.59	27.31	28.40	28.45	35.32	32.74	27.23	29.29
60	198.88	21.85	22.05	23.14	28.05	25.07	18.12	21.63

From: White
To: Gold

Threads: 16
TTRT: 25ms

LLC Buffers: 48K
MTU: 4192 Bytes

TABLE 104: TWO PROCESSORS, 33RD TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	173.08	38.23	34.59	36.67	36.67	35.78	35.96	36.80
12	27.31	25.49	24.76	25.91	29.46	28.90	29.30	28.88
20	95.57	49.15	54.61	52.43	49.52	51.63	50.80	52.27
28	118.33	60.07	54.61	52.43	50.97	53.58	52.93	53.12
36	209.35	54.61	50.97	50.97	56.80	55.34	55.75	54.55
44	209.09	49.15	50.97	49.52	50.97	50.84	52.67	54.52
52	32.77	49.15	50.97	49.52	45.15	45.12	45.94	47.08
60	23.67	38.23	37.14	42.65	40.99	37.17	39.92	35.78

From: White
To: Gold

Threads: 8
TTRT: 8ms

LLC Buffers: 56K
MTU: 4192 Bytes

TABLE 105: TWO PROCESSORS, 34TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	49.15	40.05	36.67	35.89	36.62	36.59	36.06
12	30.04	30.95	26.21	25.91	28.64	28.67	28.70	28.35
20	105.33	60.07	52.79	50.97	52.43	52.43	52.06	52.23
28	337.09	60.07	50.97	52.43	53.16	52.61	54.27	53.85
36	199.34	54.61	50.97	50.97	53.16	52.43	54.27	53.63
44	105.33	49.15	50.97	50.97	50.97	51.63	50.39	52.63
52	178.40	36.41	41.87	49.52	41.61	47.13	48.51	48.04
60	133.80	32.77	35.32	39.79	45.20	46.24	37.52	34.26

From: White
To: Gold

Threads: 16
TTRT: 8ms

LLC Buffers: 56K
MTU: 4192 Bytes

TABLE 106: TWO PROCESSORS, 35TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	36.41	35.11	36.67	34.95	35.57	36.16
12	27.31	23.67	24.76	25.82	29.73	29.44	29.54	28.82
20	105.33	49.15	50.97	50.97	51.70	51.63	51.26	51.38
28	704.51	54.61	54.61	52.43	52.43	53.58	52.89	53.60
36	330.41	54.61	50.97	50.97	51.70	53.58	54.27	55.27
44	219.06	60.07	54.61	50.97	51.70	53.58	52.52	52.41
52	101.68	54.61	41.87	45.15	45.20	47.86	50.54	48.87
60	168.13	52.79	36.41	42.36	41.75	38.63	38.67	39.02

From: White
To: Gold

Threads: 8
TTRT: 5ms

LLC Buffers: 56K
MTU: 4192 Bytes

TABLE 107: TWO PROCESSORS, 36TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	43.69	36.41	36.67	35.89	35.37	35.56	36.47
12	21.85	25.49	25.49	26.70	28.64	28.26	28.49	28.94
20	87.99	38.23	50.97	52.43	48.48	47.13	52.47	51.80
28	158.38	43.69	50.97	49.52	50.97	49.93	51.22	53.56
36	327.38	43.69	43.69	49.52	50.97	49.93	52.14	52.75
44	32.77	54.61	50.97	49.52	51.70	50.97	51.22	52.16
52	30.04	41.87	49.15	45.63	43.74	44.65	46.88	49.18
60	23.67	34.59	38.23	34.05	38.72	39.83	42.78	36.43

From: White
To: Gold

Threads: 16
TTRT: 5ms

LLC Buffers: 56K
MTU: 4192 Bytes

TABLE 108: TWO PROCESSORS, 37TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	38.23	38.23	35.89	35.89	35.37	36.16	36.47
12	30.04	27.31	27.31	25.91	28.16	27.72	27.61	28.12
20	185.69	49.15	49.15	48.06	47.02	48.82	49.89	49.57
28	32.77	49.15	47.33	49.52	48.06	50.97	52.93	50.38
36	245.90	49.15	43.69	45.98	50.24	50.84	53.35	50.26
44	87.99	54.61	45.51	49.52	45.56	48.96	51.26	49.38
52	144.99	49.15	43.69	38.40	41.92	39.66	42.78	40.30
60	114.69	28.22	29.34	27.95	34.41	32.18	30.40	30.66

From: White
To: Gold

Threads: 8
TTRT: 11ms

LLC Buffers: 56K
MTU: 4192 Bytes

TABLE 109: TWO PROCESSORS, 38TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	149.51	32.77	36.41	35.89	35.89	36.20	36.39	36.48
12	30.04	21.85	25.49	25.42	28.16	28.56	28.78	28.87
20	105.33	43.69	50.97	50.97	50.97	51.81	51.60	52.24
28	32.77	43.69	54.61	50.97	52.43	53.58	54.36	52.38
36	32.77	60.07	58.25	52.43	50.97	53.40	53.49	52.95
44	502.44	65.54	54.61	52.12	52.43	52.61	52.93	53.40
52	118.33	60.07	43.69	46.60	47.02	51.81	50.08	46.42
60	27.31	52.79	32.40	41.92	44.83	40.43	38.40	35.53

From: White
To: Gold

Threads: 16
TTRT: 11ms

LLC Buffers: 56K
MTU: 4192 Bytes

TABLE 110: TWO PROCESSORS, 39TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	32.77	34.59	36.67	35.89	36.20	35.35	35.75
12	30.04	27.31	24.76	26.70	28.28	30.01	29.03	28.99
20	136.53	54.61	54.61	48.06	50.97	51.63	50.84	51.26
28	105.33	49.15	54.61	50.97	52.43	50.05	53.39	54.07
36	87.99	54.61	50.97	50.97	52.43	51.81	53.81	54.97
44	355.59	60.07	50.97	48.06	48.06	50.84	53.39	53.11
52	85.26	60.07	43.69	46.60	41.32	46.09	50.95	49.18
60	112.87	30.95	38.23	38.07	48.48	37.84	41.38	36.57

From: White
To: Gold

Threads: 8
TTRT: 25ms

LLC Buffers: 56K
MTU: 4192 Bytes

TABLE 111: TWO PROCESSORS, 40TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	34.59	37.45	37.45	35.37	36.60	36.58
12	21.85	29.13	24.03	27.67	27.67	28.16	28.23	28.48
20	32.77	54.61	50.97	48.06	48.06	51.63	50.87	52.44
28	209.35	49.15	54.61	50.97	52.43	53.40	52.47	52.92
36	190.89	38.23	54.61	50.97	51.70	50.84	53.39	52.44
44	353.17	38.23	50.97	52.43	49.20	50.84	52.52	55.20
52	32.77	60.07	49.15	44.52	45.15	45.35	46.79	48.13
60	27.31	32.77	32.98	40.57	44.52	35.98	39.81	35.67

From: White
To: Gold

Threads: 16
TTRT: 25ms

LLC Buffers: 56K
MTU: 4192 Bytes

TABLE 112: TWO PROCESSORS, 41ST TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	34.59	35.11	36.67	36.20	36.39	36.60
12	27.31	23.67	26.94	26.30	29.25	28.93	29.74	28.92
20	363.18	43.69	47.33	50.97	46.60	52.43	52.06	53.33
28	367.47	38.23	45.51	52.43	50.97	55.34	53.64	52.21
36	30.04	36.41	45.51	44.78	44.52	45.43	48.52	42.86
44	151.55	36.77	25.33	24.74	26.24	28.67	26.12	23.80
52	198.88	18.31	17.82	20.99	20.65	22.50	19.65	17.03
60	17.29	16.38	14.45	16.20	26.67	25.20	14.48	12.27

From: White
To: GoldThreads: 8
TTRT: 8msLLC Buffers: 40K
MTU: 4192 Bytes**TABLE 113: TWO PROCESSORS, 42ND TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	34.59	35.11	36.67	36.20	36.39	36.60
12	27.31	23.67	26.94	26.30	29.25	28.93	29.74	28.92
20	363.18	43.69	47.33	50.97	46.60	52.43	52.06	53.33
28	367.47	38.23	45.51	52.43	50.97	55.34	53.64	52.21
36	30.04	36.41	45.51	44.78	44.52	45.43	48.52	42.86
44	151.55	36.77	25.33	24.74	26.24	28.67	26.12	23.80
52	198.88	18.31	17.82	20.99	20.65	22.50	19.65	17.03
60	17.29	16.38	14.45	16.20	26.67	25.20	14.48	12.27

From: White
To: GoldThreads: 16
TTRT: 8msLLC Buffers: 40K
MTU: 4192 Bytes**TABLE 114: TWO PROCESSORS, 43RD TEST RESULTS**

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	40.78	35.11	36.67	35.78	35.96	36.06
12	24.58	27.31	26.21	25.42	25.99	29.73	29.69	29.41
20	87.99	54.61	48.06	50.97	46.60	51.63	52.89	51.26
28	398.68	54.61	49.15	50.97	46.60	51.94	53.81	51.61
36	841.05	49.15	47.33	35.49	38.82	45.91	45.43	41.45
44	20.94	29.13	29.86	32.02	26.63	24.80	27.30	25.61
52	20.94	28.22	24.09	20.07	20.49	20.55	18.29	16.41
60	20.94	22.76	15.62	16.84	14.03	17.62	13.67	12.74

From: White
To: GoldThreads: 8
TTRT: 5msLLC Buffers: 40K
MTU: 4192 Bytes

TABLE 115: TWO PROCESSORS, 44TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	30.04	38.23	34.59	30.56	34.33	36.20	36.37	36.07
12	32.77	29.13	26.21	21.96	27.67	27.62	28.26	28.93
20	336.33	49.15	44.42	41.69	47.70	44.64	48.24	46.53
28	22.39	38.59	29.09	22.83	37.34	37.23	39.07	36.02
36	14.07	22.76	18.37	13.99	20.04	20.71	17.11	17.06
44	9.71	11.74	15.23	10.09	10.28	12.13	12.24	10.59
52	8.60	6.40	9.25	9.83	7.40	8.81	8.37	8.24
60	6.75	8.45	8.67	9.16	7.18	9.01	6.95	8.27

From: White

Threads: 16

LLC Buffers: 40K

To: Gold

TTRT: 5ms

MTU: 4192 Bytes

TABLE 116: TWO PROCESSORS, 45TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	34.59	36.67	36.67	35.37	35.35	35.75
12	21.85	29.13	28.40	25.02	29.13	29.44	28.52	29.20
20	209.35	54.61	47.33	50.97	49.52	52.61	52.01	50.79
28	72.82	43.69	50.97	52.43	52.43	52.61	53.81	53.35
36	30.04	32.77	38.96	41.84	45.20	46.01	47.17	45.76
44	209.35	26.40	31.68	29.63	26.39	28.94	27.35	24.47
52	23.67	24.94	26.42	24.97	20.58	18.17	19.59	20.01
60	23.67	18.20	19.70	18.59	21.62	22.31	15.22	14.55

From: White

Threads: 8

LLC Buffers: 40K

To: Gold

TTRT: 11ms

MTU: 4192 Bytes

TABLE 117: TWO PROCESSORS, 46TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	34.59	36.67	36.67	35.78	36.37	36.27
12	27.31	25.49	26.21	26.21	27.67	30.55	31.15	29.34
20	118.33	60.07	47.33	48.06	49.52	50.84	50.88	50.90
28	219.06	54.61	54.61	52.43	52.43	52.61	54.27	52.96
36	32.77	43.69	43.69	43.07	38.70	42.65	47.77	42.97
44	20.94	30.95	24.60	39.08	29.80	28.13	25.86	28.63
52	20.94	18.57	22.78	24.66	22.02	21.26	18.62	19.02
60	21.85	18.02	20.62	17.74	24.82	19.41	17.07	14.54

From: White

Threads: 16

LLC Buffers: 40K

To: Gold

TTRT: 11ms

MTU: 4192 Bytes

TABLE 118: TWO PROCESSORS, 47TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	36.41	36.67	36.67	36.62	36.80	36.47
12	30.04	25.49	26.21	26.70	30.46	29.47	29.15	28.21
20	199.34	49.15	54.61	50.97	52.43	50.84	50.87	52.23
28	622.59	65.54	54.61	50.97	48.06	52.43	53.47	54.03
36	136.53	38.23	47.33	42.29	40.90	46.29	42.24	41.95
44	21.85	24.94	29.45	28.02	24.57	25.73	19.76	22.86
52	20.48	20.68	17.63	19.46	16.82	15.81	14.08	16.59
60	15.93	22.06	15.48	17.38	18.20	14.40	11.59	10.89

From: White
To: Gold

Threads: 8
TTRT: 25ms

LLC Buffers: 40K
MTU: 4192 Bytes

TABLE 119: TWO PROCESSORS, 48TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	38.23	34.59	35.11	36.67	36.20	36.17	36.16
12	32.77	23.67	26.58	27.67	28.16	28.90	28.75	28.30
20	118.33	54.61	58.25	54.61	49.52	50.84	51.18	51.60
28	253.69	49.15	58.25	49.52	50.97	51.81	53.39	50.76
36	30.04	30.95	37.14	36.32	40.21	41.76	37.38	39.04
44	26.40	20.39	24.88	21.32	24.71	26.89	24.72	22.68
52	21.85	14.93	14.40	17.64	17.74	13.89	13.84	13.94
60	18.20	12.85	13.86	15.15	18.12	12.20	13.85	12.18

From: White
To: Gold

Threads: 16
TTRT: 25ms

LLC Buffers: 40K
MTU: 4192 Bytes

TABLE 120: TWO PROCESSORS, 49TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	32.77	33.55	31.55	32.77	31.95	31.86
12	30.04	29.13	31.68	31.55	31.55	31.84	31.46	31.55
20	249.40	60.07	54.61	52.43	50.97	52.43	50.14	49.30
28	209.35	65.54	54.61	52.43	52.43	52.61	52.93	51.52
36	32.77	54.61	58.25	52.43	54.61	54.37	52.47	51.58
44	190.89	60.07	54.61	53.16	50.97	52.61	52.47	51.84
52	372.93	38.23	50.97	52.43	42.65	45.78	44.43	40.78
60	136.53	43.69	47.33	51.70	45.56	36.85	37.14	29.40

From: White
To: Gold

Threads: 8
TTRT: 8ms

LLC Buffers: 48K

Max Throughput Prediction Test
MTU: 4352 Bytes

TABLE 121: TWO PROCESSORS, 50TH TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	30.95	32.77	32.77	34.33	34.22	34.58	34.38
12	30.04	32.77	29.49	29.86	29.73	29.44	30.56	30.48
20	235.07	60.07	45.51	48.06	46.60	43.23	43.40	44.63
28	367.47	38.23	47.33	48.06	48.06	43.69	45.30	46.27
36	270.83	43.69	43.69	49.52	37.97	34.24	33.96	35.87
44	260.58	60.07	43.69	46.60	17.51	15.19	15.35	17.34
52	176.76	49.15	43.69	44.52	8.62	7.62	7.87	8.10
60	209.35	35.50	33.86	34.59	6.45	6.15	5.99	6.27

From: Gold-50MHz
To: White-50MHz

Threads: 8
TTRT: 8ms

LLC Buffers: 48K
MTU: 4352 Bytes

TABLE 122: TWO PROCESSORS, 51ST TEST RESULTS

Window Size (K bytes)	File A Mbps	File B Mbps	File C Mbps	File D Mbps	File E Mbps	File F Mbps	File G Mbps	File H Mbps
4	32.77	32.77	34.59	35.89	34.33	34.95	34.58	34.86
12	30.04	30.95	30.58	30.95	29.25	30.59	30.13	30.05
20	264.57	54.61	50.97	48.06	42.65	43.79	44.64	45.13
28	105.33	54.61	54.61	50.97	47.02	45.78	46.63	46.44
36	32.77	54.61	47.33	46.60	33.89	33.87	33.01	33.48
44	32.77	49.15	47.33	52.43	13.10	15.06	13.20	13.21
52	163.84	41.87	43.69	40.83	7.82	6.95	7.32	7.05
60	27.31	29.13	29.34	29.75	5.06	5.87	5.80	5.81

From: White-50MHz
To: Gold-50MHz

Threads: 8
TTRT: 8ms

LLC Buffers: 48K
MTU: 4352 Bytes

APPENDIX F: GLOSSARY OF TERMS

802.2	IEEE standard for the Logical Link Control.
ACK	Acknowledge. A network packet acknowledging the receipt of data.
ARP	Address Resolution Protocol. A TCP/IP protocol to translate an IP address into a MAC address.
ANSI	American National Standards Institute. A private organization that coordinates some United states standards-making. Represents the United States to the International Standards Organization.
ARPA	Advanced Research Projects Agency. A Department of Defense agency that has helped fund many computer projects including ARPANET, the Berkeley version of Unix and TCP/IP. ARPA use to be known as DARPA.
ARPANET	Advanced Research Projects Agency Network. A Department of Defense sponsored network of military and research organizations. Replaced by the Defense Data Network (DDN).
ASIC	Application-Specific Integrated Circuits.
asynchronous	FDDI term for data transmission where all requests for service contend for a pool of ring bandwidth.
bandwidth	The amount of data that can be moved through a particular communications link. FDDI has a bandwidth of 100 Mb/s.
beacon	A token ring packet that signals a serious failure on the ring.
BER	Bit Error Rate.
bps	Bits per second. Transmission speed over some media.
CCITT	<i>Comite Consultatif International Telegraphiques et Telephonique</i> (Consultative Committee for International Telephone and Telegraph). Standards-making body administered by the International Telecommunications Union.
DARPA	Defense Advanced Research Projects Agency. See ARPA.

DAS	Dual Attached Stations. FDDI term for a node that is attached to both the primary and secondary fiber optic cables (as opposed to a node that is connected to the ring via a concentrator or not dual attached).
DDN	Defense Data Network. A network for the Department of Defense and their contractors based on the TCP/IP and X.25 networking protocols.
DLL	
DMA	Direct Memory Access. This is a device (controller) for controlling the transfer of data directly to or from the memory without involving the processor. The DMA controller becomes the bus master and directs the reads or writes between itself and memory.
DNS	Domain Name System. A mechanism used in the Internet for translating names of host computers into addresses. The DNS also allows host computers not directly on the Internet to have registered names in the same style.
FDDI	Fiber Distributed Data Interface. A 100 M/bps fiber optic LAN standard based on the token ring.
FTP	File Transfer Protocol. FTP is the Internet standard for file transfer. FTP was designed from the start to work between different hosts, running different operating systems and using different file structures. RFC 959 is the official specification for FTP.
ICMP	Internet Control Message Protocol. ICMP is often considered part of the IP layer. It communicates error messages and other conditions that require attention. ICMP messages are transmitted within IP datagrams. RFC 792 contains the official specification of ICMP.
IEEE	Institute of Electronic and Electrical Engineers. A leading standard-making body in the United States, responsible for the 802 standards for local area networks.
IGMP	Internet Group Management Protocol. IGMP lets all the systems on a physical network know which hosts currently belong to which multicast groups. This information is required by the multicast routers, so they know which multicast datagrams to forward onto which interfaces. IGMP is defined in RFC 1112.

Internet	A collection of networks that share the same namespace and use the TCP/IP protocols.
IP	Internet Protocol. The network layer protocol for the Internet.
ISO	International Standards Organization.
LAN	Local area network. Usually refers to Ethernet or token ring networks.
LLC	Logical Link Control. The upper portion of the data link layer, defined in the IEEE 802.2 standard. The logical link control layer presents a uniform interface to the user of the data link service, usually a network layer. Underneath the LLC sublayer of the data link layer is a Media Access Control (MAC) sublayer. The MAC sublayer is responsible for taking a packet of data from the LLC and submitting it to the particular data link being used.
MAC	Media Access Control. This layer provides fair and deterministic access to the medium.
Mbps	Million bits per second. 2^{20} bits of information (usually used to express a data transfer rate; as in, 1 megabit/second - 1 Mbps).
MTU	Maximum transfer unit. The biggest piece of data that can be transferred by the data link layer.
NAK	Negative acknowledgment. Response to nonreceipt or receipt of a corrupt packet of information.
NFS	Network File System. A distributed file system developed by Sun Microsystems and widely used on TCP/IP systems.
NIS	Network Information Service. Name service in the Sun Open Network Computing (ONC) family.
NPI	Network Peripheral Inc. The manufacturer of the FDDI interface cards used in this investigation on the Sun SPARC workstations.
NRZI	Nonreturn-to-Zero Inverted. NRZI is an example of differential encoding. In differential encoding, the signal is decoded by comparing the polarity of adjacent signal elements rather than determining the absolute value of a signal element.
OSI	Open System Interconnection.
PCM	Physical Connection Management.

PHY	Physical Layer. PHY provides the media independent functions associated with the OSI physical layer.
PMD	Physical Medium Dependent Layer. PMD specifies the transmitters, receivers and other associated hardware
PROM	Programmable Read-Only Memory.
RARP	Reverse Address Resolution Protocol.
RISC	Reduced Instruction Set Computer. Generic name for CPUs that use a simpler instruction set than more traditional designs. The Sun SPARC workstation uses RISC technology.
SMT	Station Management document. This layer provides the capability to monitor the FDDI network. SMT can provide services such as node initialization, bypassing faulty nodes and recovery.
SPARC	Scalable Processor Architecture. A reduced instruction set (RISC) processor developed by Sun and licensed by several vendors including AT&T and Texas Instruments.
SUN	Stanford University Network. This name was given for a printed circuit board developed in 1981 that was designed to run the UNX! operating system.
TCP/IP	Transmission Control Protocol/Internet Protocol. This is a common shorthand which refers to the suite of application and transport protocols which run over IP. These include FTP, Telnet, SMTP, and UDP.
THT	Token holding timer. Token ring and FDDI term for the amount of time a node can transmit data before sending the token back out to the ring.
TTRT	Target token rotation time. A term used in FDDI to set performance parameters. The TTRT serves as a measure of expected delay and is used, among other things, to set time-out parameters.
UDP	User Datagram Protocol.

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